Text and References To Accompany "Map Showing the Thickness and Character of Quaternary Sediments in the Glaciated United States East of the Rocky Mountains"

By DAVID R. SOLLER

A discussion of map components and sediment distribution and lists of references for a regional, three-dimensional map of glacial deposits

U.S. GEOLOGICAL SURVEY BULLETIN 1921

Return to Title Page

CONTENTS

FIGURES

METRIC CONVERSION FACTORS

For readers who wish to convert measurements from the inch-pound system of units to the metric system of units, the conversion factors are listed below:

Multiply inch-pound unit	By	To obtain metric unit
square mile (mi^2)	2.590	square kilometer (km^2)
foot (ft)	.3048	meter (m)

Text and References To Accompany "Map Showing the Thickness and Character of Quaternary Sediments in the Glaciated United States East of the Rocky Mountains"

By David R. Soller

Abstract

A 1:1,000,000-scale map of Quaternary deposits has been compiled for the glaciated area of the United States east of the Rocky Mountains (that is, the area covered by the Laurentide ice sheets). Parts of southern Ontario, areas beneath the Great Lakes, and parts of the submerged eastern seaboard are also included on the map. The map has three components that, together, provide the first regional three-dimensional view of these deposits. These map components are the surface distribution of Quaternary sediments, the total thickness of Quaternary sediments, and the distribution of significant buried Quaternary units. For many areas, this is the first map of Quaternary sediment thickness published at any scale. This report provides supporting information for the map, preliminary interpretations of sediment distribution, and the list of geologic sources used to generate the map.

Within the mapped area, there is a particular need for three-dimensional geologic mapping to support decisions on water resources and land use. Approximately 40 percent of the U.S. population resides within the mapped area, which is less than one-quarter the size of the conterminous United States. This map is intended to supplement the more detailed mapping on which it is based and is designed to be a regional planning tool.

Through the Pleistocene, large deposits of thick glacial sediment accumulated between certain late Wisconsinan glacial lobes, on bedrock topographic highs, whereas relatively thin deposits generally accumulated in the adjacent bedrock lowlands occupied by drainage and ice lobes. The lithology of the bedrock and its resistance to erosion in part controlled the patterns of ice lobation and the distribution of thick sediment. On a local scale, the spatial relation of these sediment masses to ice lobation has been suggested in places, and a regional correlation may have been assumed. This map provides the first comprehensive, regional view of glacial sediment thickness to permit such a correlation to be assessed.

SECTION 1—MAP DESCRIPTION AND GENERAL COMMENTS

INTRODUCTION

This Bulletin is a companion to a series of four 1:1,000,000-scale maps that portray the thickness and character of Quaternary sediments within a part of the area covered by the Laurentide ice sheets (Soller, in press a,b,c,d). The mapped area encompasses the glaciated United States east of the Rocky Mountains and also includes parts of southern Ontario, areas beneath the Great Lakes, and part of the Atlantic offshore area (fig. 1). This series of maps, hereafter referred to in places as the "Quaternary sediments map," is a result of regional synthesis and interpretation of available Quaternary geologic data, derived from about 850 sources of information. This section describes the map units, map compilation, and regional patterns of sediment distribution, whereas section 2 contains the geologic source data and a qualitative assessment of data reliability for each State

---

Manuscript approved for publication March 21, 1990.

The three components of the map combine to provide the first regional, three-dimensional view of these deposits. These map components are the surface distribution of Quaternary sediments, the total thickness of Quaternary sediments, and the distribution of significant buried Quaternary units. Quaternary sediments include glacial and Holocene sediments. Subsurface information is not available for most of the mapped area, and, therefore, the depiction of buried units is uneven. Where buried units are shown, the complex geologic settings in which they occur are greatly simplified because of the small scale of this map series.

This map differs in concept from most published State and regional glacial geologic maps, which generally use stratigraphic or geomorphic map units. Those maps show the chronology of geologic events such as ice advances or retreats, as determined by the glacial deposits at the surface. Regional maps of continental glacial deposits such as the "Glacial Map of the United States East of the Rocky Mountains" (Flint, 1959) and the "Quaternary Geologic Atlas of the United States" (for example, Lineback and others, 1983) are examples of the traditional, event-oriented approach to mapping. The Quaternary sediments map complements event-oriented maps by showing the thickness and character of glacial sediments without regard to age of the deposit.

Population growth and the resulting increase in demand for agricultural production, construction materials, land development, waste-disposal sites, and ground-water resources have created a growing need for geologic maps that can be directly applied to hydrologic, environmental, and land-use problems. The type of geologic map most appropriate for these applications depicts the texture and other physical aspects of the sediments or rocks to a specified depth; in other words, it is a texturally oriented, three-dimensional geologic map. An effective technique for three-dimensional geologic mapping and applications to hydrogeologic and land-use studies was discussed by Kempton and Cartwright (1984). Their technique is based on three-dimensional lithostratigraphic mapping to a specified depth; map units show the vertical succession of deposits (the stack-unit concept discussed by Kempton, 1981). These maps require detailed subsurface lithologic and stratigraphic information, surficial geologic mapping, and soil mapping. The stack-unit map can directly support water- and land-use studies, especially when combined with other data such as hydrogeologic, topographic, and land-use information. Examples of geologic map investigations that have been applied to water- and land-use issues include, but are certainly not limited to, the map folio of the Hartford North (Connecticut) quadrangle (Pessl and others, 1972), the San Francisco Bay region study (Kockelman, 1976), the Baltimore-Washington urban area study (Froelich and others, 1980), the urban-planning examples given in Robinson and Spieker (1978), and the county-scale geologic and planning studies in Illinois (Hackett and McComas, 1969; Bergstrom and others, 1976; Hunt and Kempton, 1977; Berg and others, 1984).

The glaciated region of the United States depicted in this map series has a particular need for three-dimensional geologic mapping that can support decisions on water-resource and land-use issues including waste-disposal siting and non-point-source pollution. Approximately 40 percent of the U.S. population resides within the mapped area, which is less than one-quarter the size of the conterminous United States. The region also contains a major portion of the Nation's agricultural and industrial capacity.

This map series is a regional overview of the three-dimensional distribution of sediments for a large area and is intended to supplement the more detailed work on which it is based. I hope that this series of maps will generate interest in more detailed three-dimensional geologic mapping of these, and other, deposits. Particularly in populated areas, detailed mapping is vital to the site-specific planning and assessment of the effects of human activities at and beneath the land surface. In contrast, regional maps such as the four maps of this series serve to place local, detailed mapping in context, to permit the extrapolation of data into unmapped areas, and to depict large-scale, regional geologic features and patterns that are beyond the scope of detailed, local mapping. This series of maps is also a regional planning document that can assist in setting priorities for areas in need of more detailed mapping; subsequent detailed mapping should then be incorporated into an updated regional map. Geologic mapping is an iterative process, and the maps of this series should be considered as only the initial regional view of the glacial sedimentary framework east of the Rocky Mountains.

Acknowledgments

During map compilation and production, I sought advice from many individuals in different disciplines. These people have contributed to the generation of the map, and I am grateful for their help. I particularly thank Byron D. Stone of the U.S. Geological Survey (USGS) for his suggestions on map concept and project scope, John P. Kempton and Richard C. Berg (Illinois State Geological Survey) for their encouragement to pursue new techniques, Kenneth J. Lanfear, Will R. Stettner, and James R. Estabrook (USGS) for assistance in the technical aspects of map digitization and production, and Carl Koteff (USGS) for his efforts in originating this project.

I also thank the many geologists consulted during this map project for their willingness to share information and insight, for their advice on mapping interpretations, and for their comments during map review. Their names are listed below; I apologize if I have inadvertently omitted anyone.

Atlantic offshore—Robert N. Oldale and Sally W. Needell (both USGS), Francis S. Birch (University of New Hampshire), Joseph T. Kelley (University of Maine), Ralph S. Lewis (Connecticut Geological and Natural History Survey).

Connecticut—Janet R. Stone, John P. Schafer (both USGS).

Great Lakes—Richard L. Thomas (International Joint Commission, Windsor, Ontario), C.F. Michael Lewis (Bedford Institute of Oceanography, Dartmouth, Nova Scotia), Richard J. Wold (EG&G Geometrics, Sunnyvale, Calif.), Peter G. Sly (Canada Centre for Inland Waters, Picton, Ontario), Norm A. Rukavina (Canada Centre for Inland Waters, Burlington, Ontario), John P. Coakley (National Water Research Institute, Burlington, Ontario), David L. Gross (Illinois State Geological Survey), S. Jeffress Williams (USGS), Jonathan A. Fuller (Ohio Geological Survey), Allen S. Hunt (University of Vermont).

Illinois—John P. Kempton, Richard C. Berg, Paul B. DuMontelle, Thomas M. Johnson, Leon R. Follmer, Myrna M. Killey, E. Donald McKay, Jerry R. Miller (all Illinois State Geological Survey).

Indiana—Ned K. Bleuer, Gordon S. Fraser (both Indiana Geological Survey).

Iowa—George R. Hallberg, Timothy J. Kemmis, Raymond R. Anderson (all Iowa Geological Survey).

Kansas—Jane E. Denne (Kansas Geological Survey).

Kentucky—Robert C. McDowell (USGS), Martin C. Noger (Kentucky Geological Survey).

Maine—Woodrow B. Thompson, Marc C. Loiselle, E. Melanie Lanctot (all Maine Geological Survey).

Massachusetts—Byron D. Stone (USGS).

Michigan—William R. Farrand (University of Michigan), Richard L. Rieck (Western Illinois University), Robert Reed, Richard P. Bissell, William A. Walden, D. Michael Bricker, Randall L. Milstein, Mick Jones (all Michigan Geological Survey).

Minnesota—Howard C. Hobbs, Bruce M. Olsen, Gary Meyer (all Minnesota Geological Survey).

Mississippi River—Ron Pearson (U.S. Army Corps of Engineers, Rock Island, Ill.), Mike Klosterman (U.S. Army Corps of Engineers, St. Louis, Mo.), Terry Jorgenson (U.S. Army Corps of Engineers, St. Paul, Minn.).

Missouri—James H. Williams, John W. Whitfield (both Missouri Division of Geology and Land Survey).

Missouri River—Paul Barndt (U.S. Army Corps of Engineers, Omaha, Neb.).

Montana—Robert N. Bergantino (Montana Bureau of Mines and Geology), Roger B. Colton (USGS), Jack Rodgers, Robert Richardson (both U.S. Soil Conservation Service, Bozeman, Mont.), Ronald J. Soiseth (U.S. Bureau of Land Management, Malta, Mont.), John Montain (Montana State University).

Nebraska—Vince H. Dreeszen, James B. Swinehart, Raymond R. Burchett (all Nebraska Conservation and Survey Division), James L. Howerton (Nebraska Department of Roads).

New Hampshire—John E. Cotton (USGS), Robert Davis (former New Hampshire State Geologist).

New Jersey—Byron D. Stone (USGS), David P. Harper, Scott Stanford, Ron Witte (all New Jersey Geological Survey).

New York—Allan D. Randall, Forest Lyford, Andrew Cohen, Richard K. Krulikas, Herbert T. Buxton (all USGS), Ernest H. Muller (Syracuse University), Parker E. Calkin (State University of New York, Buffalo), Donald H. Cadwell, Robert J. Dineen (both New York State Geological Survey).

North Dakota—John P. Bluemle (North Dakota Geological Survey), Lee Clayton (Wisconsin Geological and Natural History Survey).

Ohio—Dennis N. Hull, Sherry L. Weisgarber, Rene L. Fernandez, Mike Angle, C. Scott Brockman, Richard R. Pavey (all Ohio Division of Geological Survey), John Voytek (Ohio Division of Water), Stanley E. Norris (USGS, retired), Jane L. Forsyth (Bowling Green University), Richard P. Goldthwait (Ohio State University), Stanley M. Totten (Hanover College, Indiana).

Ontario—Edward V. Sado, Peter Barrett, Robert J. Fulton, Robert Geddes (all Ontario Geological Survey).

Pennsylvania—George H. Crowl (Ohio Wesleyan University), Thomas M. Berg, William D. Sevon (both Pennsylvania Bureau of Topographic and Geologic Survey), Duane D. Braun (Bloomsburg University), John H. Williams, H.J. McCoy, Drew Davis, Jennifer Harden (all USGS).

Rhode Island—Herbert Johnston, John P. Schafer (both USGS), J. Allan Cain (Rhode Island State Geologist).

South Dakota—Jay P. Gilbertson, Cleo M. Christenson, George E. Duchossois, Dennis W. Tomhave, Lynn S. Hedges, Martin J. Jarrett (all South Dakota Geological Survey).

Vermont—Charles A. Ratte (Vermont State Geologist), David Butterfield, James W. Ashley (both Vermont Agency of Environmental Conservation).

Wisconsin—Lee Clayton, John W. Attig (both Wisconsin Geological and Natural History Survey), David M. Michelson (University of Wisconsin), Howard Lorenz (U.S. Soil Conservation Service, Marinette, Wis.).

DIGITAL MAP PRODUCTION AND THE BASE MAP

The maps of this series were produced by new digital cartographic techniques (Soller and others, 1990). Although a discussion of these techniques is not within the scope of this report, a few comments on digital map production and the base map are appropriate, because they affected map content. The Quaternary sediments map spans four map sheets (Soller, in press a,b,c,d). Each sheet comprises a hand-mosaicked group of 4^ox6^o quadrangles from the International Map of the World Series (1:1,000,000 scale) or Army Map Service 1:1,000,000-scale maps. Because these map sheets include as much as 12^o of latitude and longitude and because each quadrangle has unique projection parameters, the mosaic is not precise. Between certain quadrangles, gaps exist in the base map. In order to preserve the registration of the geologic information to the base map without sacrificing the spatial integrity of the digital data, entire map sheets were not digitized. Rather, the four layers of geologic information shown on the map (that is, character of sediments exposed at the surface, thickness of Quaternary sediments, buried units and surface veneer units, and miscellaneous point and line information) were digitized separately for each 4^ox6^o quadrangle and recombined onto the base map.

MAP UNITS

The map units depict the distribution of sediment textures at the surface, the total thickness of Quaternary sediments, and selected subsurface data. Different colors are used to depict surface sediment character, variations in color intensities depict thickness of Quaternary sediments, and overprinted patterns depict selected subsurface information. On these maps, Quaternary sediments include glacial and glacially related deposits, a minor amount of Pleistocene nonglacial sediments within the glaciated area, and Holocene sediments that may or may not overlie glacial deposits. The term "glacially related" refers to nonglacial sediments that owe their existence to the activity of glacial ice; for example, the lacustrine sediments deposited in outwash-dammed lakes in northern Kentucky and adjacent States by nonglacial streams. Areas of Quaternary colluvium not derived directly from glacial deposits are small and are not shown.

Existing information from about 850 sources (see section 2) was compiled and reinterpreted to make the maps of this series. The density and detail of this information varied greatly over the region; detailed, sediment-based three-dimensional maps were published for some areas, whereas glacial geologic information was lacking for other areas. An assessment of data quality and reliability for both surficial and thickness information is provided on the Quaternary sediments map and in section 2 of this report.

A three-dimensional map could show the nature and extent of every subsurface unit; however, subsurface data available for the mapped area were sparse, and only well-delineated buried units could be shown. Although subsurface stratigraphy is not well known, the total thickness of these glacial (and postglacial) deposits can be confidently estimated in most places. The Quaternary sediments map, therefore, through the thickness information, shows the generalized framework of the glacial deposits. An understanding of three-dimensional variations in sediment texture within the glacial deposits must come from future three-dimensional studies in greater detail.

Surficial Mapping

The quality of the surficial map data and extent of map coverage varied widely. A relative, and subjective, measure of the quality of the source maps and the resulting reliability of the surficial map data are shown in figure 2. In this context, the term "quality" refers to extent of coverage, level of detail, and suitability of the source maps for reinterpretation.

In general, surficial map units are defined by terrain, map scale, and mapping approach (for example, stratigraphic, geomorphic, or sediment type). As a result, map units may not correlate with units on maps in nearby areas. For example, a map that emphasizes geologic events such as ice stillstand and moraine-building, or inundation by glacial lakes, may not correlate with an adjacent map showing kinds of surficial sediments; where the event-oriented map may show a moraine composed largely of till, the sediments-oriented map shows the actual distribution of sediment types without delineating the moraine. Although surficial geologic maps of one kind or another are available for much of the region, soil survey maps were used to assist in mapping areas where geologic data were sparse. In many areas, soil surveys were useful, but in some places, for example on till plains that were inundated by glacial lakes or where eolian sand or silt occurs as a veneer over glacial deposits, the soil surveys' usefulness is limited. In rare instances, only topographic map coverage was available, and it was used to interpolate between mapped areas.

To achieve consistency in mapping across such a large area, and to unify the wide spectrum of mapping styles and glacial geologic settings, a simple, uniform classification of deposits was devised. This classification is based on the overall character of the sediment; here, "character" includes consideration of a sediment's lithology, grain size, sorting, stratification, and depositional environment and defines the texture of the sediment as well as its origin. These sediments are classified as glacial till (unsorted and unstratified sediment), coarse-grained stratified sediment, fine-grained stratified sediment, organic-rich sediment, and windblown sediment (mostly loess). Loess is largely silt; eolian sand is included in the category of coarse-grained stratified sediment and is mapped as a veneer (see section on "Subsurface Mapping").

Till

Till, the most widespread map unit, consists of material deposited in contact with glacial ice; the other sediment units on this map were sorted and deposited by water or wind. Till is a poorly sorted and generally unstratified deposit composed of particles ranging in size from clay to large boulders (fig. 3). The relative proportions of these size fractions vary greatly, resulting in a range of texture from dense and compact clayey till, in which few grains are larger than sand size, to loose, sandy till containing abundant boulders and only small amounts of the finer size fractions. Because till covers much of the mapped area, a more comprehensive discussion of its texture is provided in the section on "Sediment Texture."

Stratified Sediment

Sediment released from melting glaciers is generally sorted by running water and is found as a stratified deposit in a variety of settings including glaciolacustrine, glaciofluvial, and outwash plain. These deposits are subdivided by grain size (fig. 3). However, as shown in figure 3 and discussed below, coarse-grained and fine-grained stratified deposits have overlapping textural ranges.

Coarse-Grained Stratified Sediment

Deposits of coarse-grained stratified sediment generally consist of layered sand and gravel, with less common silt and clay beds, deposited in fluvial, glaciofluvial, deltaic, and outwash-plain settings. Holocene alluvium has also been included in this unit; in places, it is silty or clayey, and it may overlie glacial sand and gravel. In many valleys, thick glacial meltwater sediments underlie thin Holocene alluvium. During deposition of coarse-grained stratified sediment, changes in flow regime and sediment supply were common, and sediment texture varies correspondingly. Thus, some interbedded fine-grained sediment is included in this unit (see fig. 3). Eolian sand, which has a patchier and more limited distribution than loess, is likewise shown only as a veneer (of coarse-grained stratified sediment).

In some areas, outwash in major valleys dammed tributary stream valleys, creating lakes behind the outwash. Late Wisconsinan lake sediments in tributaries in southern Illinois, southern Indiana, and northern Kentucky formed in this way. In many places, these lakes formed outside the limit of glaciation and thus contain sediments of nonglacial or periglacial origin. Because these lake sediments are related to glacial action, they are included on the map. Some of these lake sediments and some fluvial deposits (for example, those along the western margin of the mapped area in Nebraska and in the Mississippi River valley in Missouri) are so far beyond the limit of glaciation that their relation to glacial processes is highly speculative.

In Nebraska, near the western limit of glaciation, fluvial sand and gravel of Pleistocene age derived from western sources are interbedded with eastern-source glacial outwash. Of necessity, these western-source sediments have been included in this unit. Some of the section is interbedded loess, or loess reworked and deposited as a silty fluvial unit; this loess is especially common in the upper part of the section but could not be shown separately at this map scale.

Fine-Grained Stratified Sediment

Deposits of fine-grained stratified sediment generally are clay, silt, and very fine sand but include lesser amounts of coarser material (fig. 3), commonly as interbeds. Fine-grained stratified sediments were deposited in quiet water, mostly in proglacial lakes. In some parts of the Great Lakes and the Atlantic offshore area, thick accumulations of Holocene mud overlie fine-grained stratified glacial-lake sediments; these muds are included in this map unit. This unit also includes the finer grained lake sediments that occur in tributaries dammed by outwash in major valleys outside the limit of glaciation. These deposits, as mentioned above, are inferred to be glacially related, but this inference is in some places highly speculative.

On old lake plains, particularly around the Great Lakes, clayey till commonly has been winnowed by lake waters or has incorporated an earlier lake deposit. These tills may superficially resemble fine- or coarse-grained stratified lake sediments, but they retain essential characteristics of till and are mapped as such. On previous maps of this region (for example, Flint, 1959), these lake plains were largely mapped as lake sediment. In Montana and North Dakota, previous maps (Colton and others, 1961, 1963) showed proglacial lakes and inferred lake deposits; these deposits, however, are quite sparse and are not shown on the Quaternary sediments map.

Organic-Rich Sediment

Organic-rich sediment, consisting mostly of peat, swamp deposits, and marsh deposits, occurs on the youngest (late Wisconsinan) glacial deposits where postglacial drainage is poor. In most areas, it occurs in relatively small patches, but, in northern Minnesota, peat is extensive and covers a poorly drained part of the glacial Lake Agassiz basin. This unit is generally less than 20 ft thick; therefore, where the total thickness of Quaternary sediments exceeds the lowest thickness value mapped (50 ft), the unit is inferred to overlie older Quaternary sediment. In such areas, organic-rich sediment is depicted as a veneer, and the unit known or inferred to lie beneath it is also mapped. Methods for portraying the veneer and the underlying unit on the map are discussed in the "Subsurface Mapping" section and in the explanation on the maps.

Loess

Loess is windblown silt and lesser amounts of sand; it covers many upland areas in the Central United States (Thorp and Smith, 1952). Across the area depicted by this Quaternary sediments map, loess thicknesses range from 0 to more than 100 ft, but loess is commonly less than 8 ft thick (Thorp and Smith, 1952) and in many places has been mixed into the underlying deposit by farm implements or natural processes. Although it is a widespread surface unit, loess is shown only where it exceeds 20 ft in thickness and then only as a veneer to avoid undue emphasis (see example in explanation on the maps and in the "Subsurface Mapping" section below). Loess is generally not shown over stratified deposits in stream valleys because it is assumed that late glacial and Holocene erosion has largely removed the loess or incorporated it into fluvial sediment (that is, into the coarse-grained stratified unit). However, near the glacial border in Nebraska, thick loess is mapped over outwash deposits.

Patchy Quaternary Sediment

Areas where Quaternary sediment does not blanket the surface are common in some places within the glacial limit. In those areas, patchy Quaternary sediment may occur with exposures of bedrock, of residuum, or of colluvium not derived from glacial deposits. The proportion of nonglacial to glacial material in these areas ranges from numerous isolated exposures of bedrock in an area of thin till to patchy, isolated exposures of till or stratified deposits on a bedrock landscape that has preserved little evidence of glaciation. In many areas, Quaternary sediment is absent or sparse both near the limit of glaciation and in mountainous or dissected areas within the glaciated region. Extensive areas of bedrock occur mostly in upland areas where Quaternary sediments are dominantly till. Therefore, the map color is the same for patchy sediment as for till, and a color pattern is used to distinguish it from areas of continuous till cover. In one broad area in the St. Lawrence lowland in northernmost New York near Lake Ontario, the patchy sediment is not till but is mostly fine-grained stratified deposits.

Geology Beneath Bodies of Water

Beneath the Atlantic Ocean, the Great Lakes, and some other large lakes, the materials are mapped where data permitted. In most lakes, however, the underlying geology and sediment thickness are unknown. To simplify map preparation and digitizing, a somewhat arbitrary division was used for lakes lacking subbottom geologic information: for relatively small lakes (for example, 5 mi^2), geologic data were extrapolated from the surrounding land, but, for larger lakes, extrapolation was not attempted.

Thickness Mapping

The quality and distribution of thickness data vary greatly because the data base ranges from detailed statewide compilations to sparse and poorly distributed control by well logs. A relative, and subjective, measure of the quality of the source maps and the resulting reliability of the thickness data are shown in figure 4. In this context, the term "quality" refers to extent of coverage and level of detail. For 11 States, this map series provides the first statewide thickness map of Quaternary deposits; it is also the first drift-thickness map for the areas under water. For nearly all of the remaining States, new or unpublished thickness data supplemented the existing maps.

The surficial character of the sediments was compiled and then used, with topography, as a guide for mapping sediment thickness in places of limited data. This procedure improved the continuity and reliability of thickness contours in many areas for two reasons. First, the contact between surficial lithologies may mark a large change in overall thickness of deposits. For example, on the Appalachian Plateau of west-central New York, uplands covered by thin deposits of till are dissected by deep, narrow valleys containing sequences of stratified, water-lain sediment commonly more than 200 ft thick. At the map scale of 1:1,000,000, the contact between till and stratified sediment closely approximates the valley wall; even where thickness data are sparse, this contact serves as the guide to constrain the thickness contours to the stratified sediment areas within the valley. Without the surficial geology as a constraint, the limited well-log data would be of use only as point data; however, where surficial geology and topography are considered, these limited data are used most effectively to project thickness contours into areas with little or no well-log data.

Second, in many areas, topographic relief is sufficient to significantly affect the thickness of the underlying sediments. Some compilations used in the preparation of these maps are so generalized that the thickness contours are not constrained by relief of the land surface. Where thick deposits in a buried valley are deeply dissected by crosscutting modern drainage, the thickness contours should not cross the low areas of the dissected terrain. On the four maps of this series, where modern stream valleys overlie buried valleys, the thickness contours that depict thick sediments in the buried valleys are generally constrained by the limits of the modern valley, especially where bedrock is exposed along valley walls.

In a few areas, because of lack of available data, the glacial sediments cannot be differentiated from underlying deposits. Beneath the thick drift of Michigan's southern peninsula, red beds of possible Jurassic age are patchily distributed (Schaffer, 1969; Rhoads and others, 1985). The distribution of these red beds is uncertain, and they are difficult to recognize on well logs; therefore, some minor part of the sediment thickness in Michigan as shown on the Quaternary sediments map may be the red beds.

Elliptical landforms, shaped and oriented by overriding ice, are common in some areas. They are generally composed of dense, compact till, but some are rock cored or entirely rock. The composition of these streamlined landforms can be determined by augering; however, because drill data are uncommon, most maps (including these) treat all oriented, streamlined landforms as a group. Drumlins are streamlined hills that are generally composed of till; in areas of thin till, these features are relatively thick accumulations of till. In New England, where till is typically less than 15 ft thick on the uplands, till beneath drumlins commonly is more than 40 ft thick. Although less thick than the lowest contour value, and of small size, drumlins are shown on the maps of this series by symbols.

Nearly all thickness and topographic data used to compile the Quaternary sediments map were reported in U.S. customary units (feet). For simplicity and accuracy during map compilation, this system was retained. The contour intervals on the map are 0–50 ft, 50–100 ft, 100–200 ft, 200–400 ft, 400–800 ft, and greater than 800 ft.

Subsurface Mapping

A three-dimensional map could, ideally, portray the nature and extent of every subsurface unit. However, the geometry and textures of nonmarine Quaternary deposits can be quite complex, varying both vertically and laterally over short distances. The data base needed to adequately predict the subsurface geometry of these units is unavailable for most areas. Although the amount and distribution of subsurface information vary greatly from State to State, enough is available to allow the Quaternary sediments map to show a cursory impression of subsurface variability and the general configuration of regional, large-scale glacial textural contrasts in the subsurface.

For some small parts of the continentally glaciated United States, the nature of subsurface glacial lithologies is sufficiently well known to permit detailed three-dimensional mapping. Most of this knowledge comes from local studies related to delineation of buried aquifers. On a somewhat less detailed scale, two notable examples of statewide three-dimensional maps are those of Illinois (Berg and Kempton, 1988, scale 1:250,000) and Connecticut (Stone and others, in press, scale 1:125,000), which show subsurface data by map units representing vertical successions of lithologic units (the stack-unit concept discussed by Kempton, 1981). These two State maps are complex and portray subsurface data effectively. However, their methods of showing detailed subsurface data are not as feasible on a regional scale of 1:1,000,000; data density and reliability are highly uneven from State to State, and, in certain areas, the deposits are too thick and the stratigraphy is too complex to be portrayed by their methods.

In general, the subsurface is not shown on the Quaternary sediments map because data are insufficient. In the areas where the subsurface is well known, the vertical succession of geologic units is depicted on the map in a generalized fashion, as a two-unit stack consisting of either the surficial unit and a well-mapped buried unit of some significance (for example, an aquifer) at some unspecified depth, or a discontinuous surface veneer of sediment and the underlying unit. These stack units include, but are not limited to, stratified sediments overlying till in a glacial lake basin, sand and gravel aquifers buried beneath till, and areas of peat or of eolian sediments (loess or eolian sand) capping older Quaternary sediments. These buried or veneer units are commonly widespread or thick and may be of economic as well as geologic significance (for example, as aquifers).

These two-unit stacks on the map do not portray the actual vertical succession of units. Where a buried coarse-grained stratified unit is depicted, it may occur at the base of section beneath till, or beneath till that contains numerous interbeds of stratified deposits and peat, or at some other position within the section, perhaps bounded above and below by till. However, the stack does indicate the occurrence of a well-known, significant buried unit. Also, where a veneer of loess is mapped over till, it is not implied that the entire section beneath the loess is till. Stratified deposits may be buried beneath or interbedded with till, as is certainly possible in areas where stack units are not shown.

Through the use of colors and patterns, the stack units emphasize either the surficial or the buried unit. For example, where a patchy veneer of peat or of fine-grained stratified lake sediment overlies a thick sequence capped by till, the till is shown as the solid map color, and the thin overlying unit appears as a pattern of thin lines whose color reflects that unit's lithology. Where the geometry of a buried unit (for example, stratified sand and gravel in a buried valley) is fairly well defined, the surficial unit is shown in a solid color, and the buried unit is represented by a dot pattern of the appropriate color. The Quaternary sediments map also shows lithologic logs from different geologic settings (for example, buried valleys and upland areas) to indicate actual variations in subsurface lithology.

FACTORS AFFECTING SEDIMENT TEXTURE AND DISTRIBUTION

Sediment Texture

Till, the most widespread unit on the Quaternary sediments map, ranges from dense and compact clayey till, in which few grains are larger than sand size, to loose, sandy till containing abundant boulders and only small amounts of the finer size fractions. Areal variations in till texture can significantly affect the rate of recharge to ground water. Also, dense, fine-textured till is a preferred medium for waste disposal. Thus, decisions concerning land use are benefited by a better understanding of till texture. Figure 5 provides a general guide to surficial till texture. This figure is based largely on textural descriptions by field mappers, supplemented by some textural analyses and in places by geologic interpretation. Regional variations in till texture reflect the effects and interactions of glacier flow, weathering, and the lithology of the underlying bedrock.

Most till was derived from the local substrate, either bedrock or previous glacial deposits. Especially outside the Great Lakes basins, bedrock lithology and till texture are closely related. Sandy till is common on coarse-grained igneous and metamorphic rock terranes and on areas underlain by coarse clastic rocks. Silty till occurs on finer grained metamorphic rocks and on sedimentary units containing sandstone, siltstone, shale, and carbonate rocks. Clayey till is common on areas of shale bedrock (for example, in the Dakotas and Montana). Glaciers that overrode older glacial sediments may have deposited a till similar in character to the underlying unit; where fine-grained glacial lake sediments were overridden by a glacier, a clayey till was commonly deposited. Figure 6 shows the general lithology of bedrock and the outlines of glacial lake basins.

The distribution of sandy, silty, and clayey till is closely related to the differential resistance of bedrock to erosion by water and ice. Erosion was most severe in the finer grained clastic and carbonate rocks, whereas coarse-grained igneous and metamorphic complexes resisted erosion more effectively. This difference in resistance is demonstrated in the Great Lakes region, where ice tended to be directed along formational strike and along the course of preglacial valleys, through zones of relatively weak rocks. The basins of Lakes Michigan, Huron, Erie, and Ontario were in large part sculpted by glacial erosion of certain Paleozoic shales, siltstones, and carbonate rocks, whereas glacial erosion beneath Lake Superior occurred dominantly in faulted Precambrian metasedimentary rocks (see Hough, 1958).

Mode of glacial sediment deposition varied depending on the topographic setting, because topography of the bedrock surface (and, for later ice advances, topography on the surface of older glacial deposits) caused ice to flow in lobes rather than as a regional, uniform sheet. In interlobate areas on many uplands, relatively coarse-grained winnowed till and coarse-grained stratified deposits were deposited in moraines. Of course, topographic setting also exerted some control on till texture outside the Great Lakes basins. For example, on the interlobate area known as the Prairie Coteau in eastern South Dakota, deposition by stagnating ice along lateral moraines produced tills somewhat siltier than the clayey tills of the lowlands to the west and northeast. Similarly, a relatively coarse till occurs in the morainal deposits of central North Dakota and South Dakota. In many lowland areas, fine-grained glacial lake sediments were deposited in basins next to ice lobes. An ice advance over the lake basin commonly produced a clay-rich till due to incorporation of the fine-grained lake sediment. A correlation of bedrock lithology, the down-ice part of glacial lake basins, and the distribution of clayey till is apparent in a comparison of figures 5 and 6.

Sediment Distribution

In places, thick glacial sediments occur only in valleys of preglacial or interglacial origin. In New England, and westward to the Appalachian Escarpment in Ohio, the glacial sediment cover is relatively thin, generally less than 20 ft thick on the uplands. However, in this region, modification of preglacial and interglacial valleys by glacial erosion produced deeply incised drainage systems, which are now partly filled with stratified glacial and Holocene sediment, locally more than 200 ft thick in major valleys. West and northwest of the Appalachian Escarpment, sediment thicknesses over a large area are commonly much greater. There, entire preglacial and interglacial drainage systems lack surface expression (for example, the Mahomet valley in Illinois and the Teays system in Ohio and Indiana). These buried valleys commonly are filled with thick interbedded till and stratified sediment. Beneath the Great Lakes, glacially overdeepened channels are partly or completely filled with till and fine-grained stratified Quaternary sediment, notably in western Lake Superior, southern Lake Huron, and eastern Lake Erie. A simplified thickness map (fig. 7) derived from the 1:1,000,000-scale maps of this series shows the largest of these thick deposits.

The most extensive accumulations of thick glacial sediment are not, however, in filled valleys and other depressions. Large areas in the southern peninsula of Michigan, western Minnesota, and eastern North Dakota and an area in eastern South Dakota, southwestern Minnesota, and western Iowa are underlain by more than 200 ft of glacial sediment (fig. 7). These thick sediment piles are composed of complex and poorly understood deposits of till and coarse-grained stratified sediment accumulated during multiple glaciations. As an example of the stratigraphic complexity in these areas, a well drilled in the Prairie Coteau region of South Dakota penetrated 868 ft of glacial sediment consisting of at least 10 layers of till and intervening gravelly (stratified?) units (South Dakota Geological Survey, written commun., 1987). Well data on the southern peninsula of Michigan indicate 800 to more than 1,200 ft of glacial sediment.

In these and other large areas of thick sediment, the texture of till and stratified sediment is coarse relative to adjacent areas of thinner sediment accumulation (for example, for Michigan, see Farrand and Bell, 1982). This contrast reflects the differing nature of glacial sedimentation between the ice-lobe basins and interlobate areas. In the ice-lobe basins, till and fine-grained stratified sediment predominate. The till is dominantly of basal origin and in places has incorporated fine-grained glaciolacustrine sediments during ice readvance. In contrast, at the ice terminus and in interlobate areas, supraglacial and extramarginal deposition was more common. Consequently, glacial sediment deposited there is dominantly coarse-grained stratified sediment and relatively coarse and poorly compacted till.

Most of these areas of thick sediment accumulation lie beneath late Wisconsinan interlobate positions (see fig. 7) on topographically high areas of the bedrock surface, whereas relatively thin deposits generally accumulated in the adjacent bedrock lowlands occupied by drainage and by ice lobes (see cross sections in fig. 8). Thick sediment did not accumulate in all interlobate areas; for example, note the area between the Lake Huron and Lake Erie lobes in Lake Erie (fig. 8, section A–A’). The absence of thick sediment there is perhaps due to the lack of a bedrock high needed to restrict the two lobes and stabilize the location of the interlobate area sufficiently to permit a thick accumulation of sediment.

Figure 8, section A–A’, shows thinning of glacial sediment up the regional slope of the bedrock, in the direction of the ice terminus near the Appalachian Escarpment (see fig. 7). In contrast, figure 8, section B–B’, shows a thickening of sediment along the lateral margin of the James lobe, westward up the regional bedrock slope. The relatively stable position of lateral margins, especially where restricted by regional slope, may account for the thick sediment in these places, in contrast to the relatively unstable margin position of an ice terminus, where thick sediment is less likely to accumulate. Figure 8, section C–C’, shows generally thin drift on the upland where the Rainy lobe-Lake Superior lobe boundary is shown, likely because that interlobate position was not stable over time. In the lowlands of the Lake Superior lobe, thick drift occurs on a bedrock high that separated two sublobes. The thick sediment in Lake Superior is in part Holocene lake sediment. The correlation among interlobate positions, thick sediment, and bedrock highs underlain by resistant bedrock is most notable for the Paleozoic sedimentary rocks of the Great Lakes region, where there is sufficient lithologic contrast and differential erosion. On the other hand, in New England, the regional predominance of resistant rock types appears to have precluded development of a similar pattern.

For many areas, it is likely that once ice lobation had become established, the ice lobes and interlobate areas recurred at the same general positions in successive glaciations, causing a gradual buildup of sediment volume in the interlobate areas. Late Wisconsinan sediment (see, for example, Mickelson and others, 1983) accounts for only a minor part of the sedimentary sequence in the interlobate areas shown in figure 7. This fact suggests that, at the regional level, the younger glaciations almost certainly did not establish radically different patterns of sediment distribution. As demonstrated by Kemmis and others (1981) and by other authors, ice traveling over a previously glaciated terrain may incorporate only a part of the underlying glacial sediment and redeposit it as till and will not commonly erode through thick glacial sediment into bedrock. The general configuration of the bedrock surface must have been established before the Pleistocene or during the early (at least pre-Wisconsinan) glaciations and probably generally followed the preglacial topography. Through successive glaciations, bedrock topographic highs separating adjacent ice lobes received additional sediment from the lateral margins of each lobe, adding to the overall thickness of sediment in the interlobate area and further establishing topographic control on ice movement. This conclusion is regionally based and may have less validity at a local scale, where the relation between bedrock topography and ice lobation may in places be lacking or be less clear (see, for example, Kemmis and others, 1981).

The largest area of thick glacial sediment in the mapped area is in Minnesota, west of the Great Lakes, and cannot be satisfactorily correlated with latest Wisconsinan lobe margin positions (fig. 7). Ice flowed into this area from two directions: the Lake Superior lobe from the northeast and the Red River and Des Moines lobes from the northwest (see discussion in Mayewski and others, 1981, p. 91–93). Ice advances from these lobes were asynchronous. In the latest Wisconsinan, the Lake Superior lobe was retreating northwestward as ice in the Red River and Des Moines lobes expanded south and east. The thick sediment lies to the west and south of the latest Wisconsinan lobe positions, in an area where interlobate positions may have existed before the latest part of the Wisconsinan.

SUMMARY

The maps of this series are a first approximation of the regional, three-dimensional distribution of Quaternary sediments over a very large area. They are intended to support additional research and detailed mapping. They are also intended to supplement the local, detailed studies from which they were compiled and should not be used to infer specific details concerning the local geologic framework. Rather, they are most useful as planning documents. As a complement to detailed mapping, regional maps such as these place local, detailed mapping in context, permit the extrapolation of data into unmapped areas, and depict large-scale, regional geologic features that are beyond the scope of detailed, local mapping.

Two general points about the Quaternary sediments map should be stressed. First, this map depicts the surface distribution of sediments and the total thickness of the Quaternary deposits; the continuation down to the pre-Quaternary surface ("bedrock") of the glacial unit that lies at the surface cannot necessarily be inferred. However, in places, the surface unit can extend to bedrock, especially where the Quaternary sediment is thin. Second, the materials-based mapping emphasis differs from that of most published State and regional surficial geologic maps, which use stratigraphic or geomorphic map units and focus on the chronology of geologic events such as ice advances or retreats or the history of glacial lakes. Because of this fundamental difference, the distribution of sediments on event-oriented maps may not agree with the distribution on these maps. For example, in many glaciated areas inundated by proglacial lakes, the surficial sediment is commonly till, somewhat altered where reworked by lake waters. On event-oriented maps, however, because of the glacial geologic history, lacustrine clay, silt, and sand are commonly mapped (inferentially) throughout a lake plain, although these deposits may be areally less common than till.

Preliminary analysis of the map patterns, in concert with information on till texture, ice lobe pattern, and bedrock lithology, suggests the following conclusions. The differential resistance of bedrock to erosion by water and ice has partly controlled till textural distribution, especially in the Great Lakes basins. Mode of deposition (for example, interlobate area, basal ice, stagnating ice) also greatly affects the texture of the deposited till. Most of the largest areas of thick glacial sediment were late Wisconsinan interlobate areas on topographically high areas of the bedrock surface, whereas relatively thin deposits generally accumulated in the adjacent bedrock lowlands occupied by drainage and by ice lobes. The lithology of the bedrock and its resistance to erosion in part controlled the pattern of ice lobation and the distribution of thick sediment. The thickness of late Wisconsinan sediment accounts for only a minor part of the sedimentary sequence in the thick drift of these interlobate areas. It is likely, therefore, that once ice lobation had become established in an area, there was a tendency for ice lobes and interlobate areas to recur at roughly the same locations in successive glaciations. Thus, the general configuration of the bedrock surface may have been established in pre-Pleistocene time or after the earliest glaciations. Through successive glaciations, the bedrock topographic highs separating adjacent ice lobes continued to receive additional sediment from the lateral margins of each lobe, adding to the overall thickness of sediment in the interlobate area and further emphasizing topographic control on ice movement.

REFERENCES CITED

Berg, R.C., and Kempton, J.P., 1988, Stack-unit mapping of geologic materials in Illinois to a depth of 15 meters: Illinois State Geological Survey Circular 542, 23 p., scale 1:250,000.

Berg, R.C., Kempton, J.P., and Stecyk, A.N., 1984, Geology for planning in Boone and Winnebago Counties: Illinois State Geological Survey Circular 531, 69 p.

Bergstrom, R.E., Piskin, Kemal, and Follmer, L.R., 1976, Geology for planning in the Springfield-Decatur region, Illinois: Illinois State Geological Survey Circular 497, 76 p.

Colton, R.B., Lemke, R.W., and Lindvall, R.M., 1961, Glacial map of Montana east of the Rocky Mountains: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–327, scale 1:500,000.

———1963, Preliminary glacial map of North Dakota: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–331, scale 1:500,000.

Farrand, W.R., and Bell, D.L., 1982, Quaternary geology of northern and southern Michigan: Lansing, Mich., Michigan Geological Survey Division, scale 1:500,000.

Flint, R.F. (committee chairman), 1959, Glacial map of the United States east of the Rocky Mountains: Boulder, Colo., Geological Society of America, scale 1:1,750,000.

Froelich, A.J., Hack, J.T., and Otton, E.G., 1980, Geologic and hydrologic map reports for land-use planning in the Baltimore-Washington urban area: U.S. Geological Survey Circular 806, 26 p.

Hackett, J.E., and McComas, Murray, 1969, Geology for planning in McHenry County: Illinois State Geological Survey Circular 438, 31 p.

Hough, J.L., 1958, Geology of the Great Lakes: Urbana, Ill., University of Illinois Press, 313 p.

Hunt, C.S., and Kempton, J.P., 1977, Geology for planning in De Witt County: Illinois State Geological Survey Environmental Geology Notes 83, 42 p.

Kemmis, T.J., Hallberg, G.R., and Lutenegger, A.J., 1981, Depositional environments of glacial sediments and landforms on the Des Moines lobe, Iowa: Iowa Geological Survey Guidebook Series, no. 6, 132 p.

Kempton, J.P., 1981, Three-dimensional geologic mapping for environmental studies in Illinois: Illinois State Geological Survey Environmental Geology Note 100, 43 p.

Kempton, J.P., and Cartwright, Keros, 1984, Three-dimensional geologic mapping: a basis for hydrogeologic and land-use evaluations: Association of Engineering Geologists Bulletin, v. 21, p. 317–335.

Kockelman, W.J., 1976, Use of USGS earth-science products by county planning agencies in the San Francisco Bay region, California: U.S. Geological Survey Open-File Report 76–547, 186 p.

Lineback, J.A., Bleuer, N.K., Mickelson, D.M., Farrand, W.R., and Goldthwait, R.P., 1983, Quaternary geologic map of the Chicago $4^{o}x6^{o}$ quadrangle, United States, in Richmond, G.M., and Fullerton, D.S., eds., Quaternary geologic atlas of the United States: U.S. Geological Survey Miscellaneous Investigations Series Map I–1420 (NK–16), scale 1:1,000,000.

Mayewski, P.A., Denton, G.H., and Hughes, T.J., 1981, Late Wisconsin ice sheets in North America, in Denton, G.H., and Hughes, T.J., eds., The last great ice sheets: New York, Wiley, p. 67–178.

Mickelson, D.M., Clayton, Lee, Fullerton, D.S., and Borns, H.W., Jr., 1983, The late Wisconsin glacial record of the Laurentide ice sheet in the United States, in Porter, S.C., ed., Late-Quaternary environments of the United States, Volume 1, The late Pleistocene: London, Longman, p. 3–37.

Pessl, Fred, Jr., Langer, W.H., and Ryder, R.B., 1972, Geologic and hydrologic maps for land-use planning in the Connecticut Valley with examples from the folio of the Hartford North quadrangle, Connecticut: U.S. Geological Survey Circular 674, 12 p.

Rhoads, B.L., Rieck, R.L., and Winters, H.A., 1985, Effects of thick drift on Quaternary landscapes in central Michigan: Michigan Academician, v. 17, p. 301–315.

Robinson, G.D., and Spieker, A.M., eds., 1978, Nature to be commanded...: U.S. Geological Survey Professional Paper 950, 95 p.

Schaffer, B.L., 1969, Palynology of the Michigan "Red Beds": East Lansing, Mich., Michigan State University, Ph.D. dissertation, 250 p.

Soller, D.R., in press a, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northeastern States, the Great Lakes, and parts of southern Ontario and the Atlantic offshore area (east of 80^{o} 31^{o} West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–A, scale 1:1,000,000.

———in press b, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern Great Lakes States and central Mississippi Valley States, the Great Lakes, and southern Ontario ($80^{o}31^{o}$ to 93^{o} West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–B, scale 1:1,000,000.

———in press c, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern and Central Plains States (90° to 102° West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–C, scale 1:1,000,000.

———in press d, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern Plains States (west of 102° West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I–1970–D, scale 1:1,000,000.

Soller, D.R., Stettner, W.R., Lanfear, K.J., and Aitken, D.S., 1990, A user's manual for a method of map scanning and digital editing for thematic map production and data-base construction: U.S. Geological Survey Circular 1054, 38 p.

Stone, J.R., London, E.H., and Langer, W.H., 1979, Map showing textures of unconsolidated materials, Connecticut Valley urban area, central New England: U.S. Geological Survey Miscellaneous Investigations Series Map I–1074–B, scale 1:125,000.

Stone, J.R., Schafer, J.P., London, E.H., and Thompson, W.B., in press, Surficial materials map of Connecticut: Reston, Va., U.S. Geological Survey, scale 1:125,000.

Thorp, James, and Smith, H.T.U. (co-chairmen, National Research Council Committee for the Study of Eolian Deposits, Division of Geology and Geography), 1952, Pleistocene eolian deposits of the United States, Alaska, and parts of Canada: Boulder, Colo., Geological Society of America, scale 1:2,500,000.

SECTION 2—SOURCES AND RELIABILITY OF MAP DATA

The four maps of this series were generated by compiling and reinterpreting existing information derived from published and unpublished maps and reports, basic data, and discussions with other geologists. Those geologists, numbering about 130 and located in the 23 States within the mapped area and in Canada, are listed in the "Acknowledgments" section. Where preliminary versions of published maps were used to generate the maps of this series, they are noted in the following list. Also, significant sources of unpublished information are included. Some stack-unit and other information on the map was interpreted from oral and written communications with scientists listed in the "Acknowledgments" section and is not noted here. The published or otherwise available sources of information, numbering about 850, are listed below.

Surface sediments, or any group of geologic units, are mapped for many purposes, resulting in maps with widely differing themes, content, complexity, and scale. For the region depicted on the maps of this series, source maps were highly varied in nature and map coverage was incomplete. This situation necessitated the adoption of a simple, materials-based classification scheme that could be applied uniformly across the entire region. Because the quality and coverage of data used in assembling these maps vary widely, the reliability of the map series also varies from place to place. Most of the map data are considered moderately reliable, in the qualitative judgment of this author. However, a moderate to major reinterpretation or synthesis of source maps was generally required to adapt them to the classification scheme of this map. In a few States, data were of high quality and reliability and were not reinterpreted. Statewide maps were not available in many States, and the map data were assembled from numerous sources. In these cases, data reliability was generally considered to be low. For many States, the available data were sparse, and map reliability was low to moderately low. In other States, refinement of data during map compilation resulted in relatively higher reliability for the map.

This section is organized alphabetically by State; data sources for the Great Lakes, the Atlantic offshore, and Canada follow the State listings. Each section begins with a brief overview of the character and thickness of the glacial deposits, followed by brief statements on data reliability and types of map data used to compile the surficial-sediment, sediment-thickness, and subsurface parts of the maps (hereafter referred to as the "Quaternary sediments map"). Where the term "map compilation" is used, it refers to compilation of the four maps of this series, not compilation of source maps.

After this introductory material, the sources are given for surficial and stack-unit information and thickness information. For some States, additional references (for example, a map showing drumlins only) are listed separately. Because the "Additional References" heading includes only those citations not listed under previous headings, the list of references identified for an additional topic (for example, drumlins) may be incomplete. The heading "Surficial and Stack-Unit Information" may be replaced by "Surficial Information" if the stack-unit information for that State was derived solely from discussions with cooperating scientists or if stack-unit information is not depicted. The format was chosen to limit the redundancies in citations. For sections containing several references, an asterisk preceding a reference denotes the primary reference(s) for that section.

CONNECTICUT

Overview of Quaternary deposits.—Thick sediment in Connecticut is confined largely to the river valleys, where areas of sediment thicknesses between 100 to 200 ft are not uncommon; in places, more than 400 ft of sediment is preserved. Coarse- and fine-grained stratified sediments, deposited by glacial meltwater in glacial lakes, account for the bulk of the valley fill. In contrast, the upland areas are mostly mantled by sandy till. Generally less than 20 ft thick, the till in upland areas is highly variable in thickness. Drumlins, composed of thicker till, are in all parts of the State. In many places, the till is patchy and bedrock exposures are numerous.

Surficial information.—Map data were compiled directly from the new State surficial materials map (Stone and others, in press, scale 1:125,000). It was readily incorporated into the Quaternary sediments map without the need for reinterpretation. The reliability of the map data is considered to be high.

Thickness information.—An unpublished map of the thickness of surficial materials, scale 1:125,000, was compiled by the senior author of the State surficial materials map from numerous well data. The reliability of the map data is considered to be high.

Subsurface information.—The lithology of subsurface units as mapped on the State surficial materials map was simplified and shown diagrammatically on the Quaternary sediments map.

Surficial and Stack-Unit Information

Stone, J.R., Schafer, J.P., London, E.H., and Thompson, W.B., in press, Surficial materials map of Connecticut: Reston, Va., U.S. Geological Survey, scale 1:125,000.

Thickness Information

Stone, J.R., 1986, Thickness of surficial materials in Connecticut: Reston, Va., U.S. Geological Survey, unpublished map, scale 1:125,000.

ILLINOIS

Overview of Quaternary deposits.—Surface sediments in Illinois are dominantly silty till, except in northeastern Illinois, where the surface till in the basin of the Lake Michigan ice lobe is more clayey. Large areas of surficial stratified deposits, generally coarse grained, are confined to the valleys of the Mississippi, Illinois, and Wabash Rivers. Fine-grained stratified deposits occur in tributary valleys of the Wabash River and near Lake Michigan. Excluding northeastern and east-central Illinois, sediment thicknesses outside river valleys seldom exceed 100 ft and are commonly less than 50 ft. In the major river valleys, 50 to 200 ft of stratified sediment commonly is preserved. In the area covered by the latest glacial advance, in northeastern Illinois, sediment thicknesses of 100 to 400 ft are common in places. Extensive preglacial and interglacial drainage networks are buried beneath the till cover; some of these old valleys contain thick coarse-grained stratified sediments that are important aquifers.

Surficial information.—The State map of Quaternary deposits (Lineback, 1979), scale 1:500,000, was used for compilation of the Quaternary sediments map. Although it is a stratigraphic map, the character of sediments within each unit is readily determined, so that extensive reinterpretation of the map units was not necessary. However, due to the stratigraphic emphasis of the map, areas of patchy surface till and numerous bedrock exposure were not delineated, and these had to be interpreted from other map sources. Overall, the reliability of the map data is considered to be high.

Thickness information.—A State map of sediment thickness (Piskin and Bergstrom, 1975), scale 1:500,000, was used to compile the Quaternary sediments map. Reliability of data was moderately high, except in areas of thin sediment cover. Based on a more modern and extensive well inventory, maps by Berg and others (1984) and Berg and Kempton (1988) were used to revise the 50- and 100-ft thickness contours and to improve data reliability overall.

Subsurface information.—The subsurface geology has been extensively studied, and statewide and county maps depicting the three-dimensional nature of the deposits have been produced by the State. For the purposes of the Quaternary sediments map, the statewide maps were adequate to depict the buried aquifers.

Surficial and Stack-Unit Information

Berg, R.C., and Kempton, J.P., 1984, Potential for contamination of shallow aquifers from land burial of municipal wastes: Champaign, Ill., Illinois State Geological Survey, scale 1:500,000.

Berg, R.C., Kempton, J.P., and Stecyk, A.N., 1984, Geology for planning in Boone and Winnebago Counties: Illinois State Geological Survey Circular 531, 69 p.

*Lineback, J.A., 1979, Quaternary deposits of Illinois: Champaign, Ill., Illinois State Geological Survey, scale 1:500,000.

Miller, J.R., Berg, R.C., Johnson, T.M., and Wehrmann, Allen, 1985, Siting a low-level radioactive waste disposal facility in Illinois: statewide criteria: Champaign, Ill., Illinois State Geological Survey and Illinois State Water Survey, contract report to Illinois Department of Public Safety, 13 p., scale 1:3,000,000. Open-file maps (1:1,000,000 scale) were obtained for map compilation.

Piskin, Kemal, and Bergstrom, R.E., 1975, Glacial drift in Illinois: thickness and character: Illinois State Geological Survey Circular 490, 35 p., scale 1:500,000.

Poole, V.L., and Sanderson, E.W., 1981, Groundwater resources in the Saline Valley Conservancy District, Saline and Gallatin Counties, Illinois: Champaign, Ill., Illinois State Geological Survey, Contract/Grant report 1981–2.

Ray, B.W., Fehrenbacher, J.B., Rehner, R., and Acker, L.L., 1976, Soil survey: Stephenson County, Illinois: University of Illinois Agricultural Experiment Station Soil Report 99, 132 p., scale 1:126,720.

Thickness Information

Berg, R.C., and Kempton, J.P., 1988, Stack-unit mapping of geologic materials in Illinois to a depth of 15 meters: Illinois State Geological Survey Circular 542, 23 p., scale 1:250,000. Preliminary version obtained for map compilation.

Berg, R.C., Kempton, J.P., and Cartwright, Keros, 1984, Potential for contamination of shallow aquifers in Illinois: Illinois State Geological Survey Circular 532, 30 p., scale 1:500,000.

Piskin, Kemal, and Bergstrom, R.E., 1975, Glacial drift in Illinois: thickness and character: Illinois State Geological Survey Circular 490, 35 p., scale 1:500,000.

INDIANA

Overview of Quaternary deposits.—Surface sediments in Indiana are dominantly silty till, except in northeastern Indiana, where the surface till in the basin of the Lake Erie ice lobe is more clayey. Large areas of surficial stratified deposits, generally coarse grained, are confined to a broad area in northwestern Indiana and to the valleys of the Wabash and Ohio Rivers and major tributaries. Fine-grained stratified deposits are mostly in tributary valleys of the Wabash and Ohio Rivers. In the northern half of the State, sediment thickness is commonly 50 to 400 ft, the greater thicknesses occurring over the preglacial and interglacial valleys buried by the sediment cover and in the interlobate area of north-central Indiana. Beyond the southern limit of the latest ice advance (Woodfordian), the thickness of sediments is generally less than 50 ft. In places, these older deposits have been eroded, and bedrock is exposed.

Surficial information.—The Quaternary sediments map was compiled mainly from eight 1:250,000-scale surficial geologic maps published between 1966 and 1979. The map units are not directly applicable to the classification scheme used for the Quaternary sediments map, and so a moderate amount of reinterpretation was required, especially for the stratified deposits. The overall reliability of the data is therefore considered to be moderately high.

Thickness information.—A State map of sediment thickness (Gray, 1983), scale 1:500,000, was used for the Quaternary sediments map. The map is relatively current and relies on a large number of data points (roughly 60,000); the reliability of the map is therefore considered to be moderately high.

Subsurface information.—The character and geometry of glacial units in the subsurface are not well known in Indiana. Despite the lack of subsurface data, a limited number of subsurface units are shown on the Quaternary sediments map on the basis of extrapolation of the trends of buried units depicted in Illinois.

Surficial Information

Bleuer, N.K., Melhorn, W.N., and Fraser, G.S., 1982, Geomorphology and glacial history of the Great Bend area of the Wabash Valley, Indiana: Geological Society of America, North Central Section, 16th Annual Meeting, Field Guidebook, Field trip no. 2, 63 p.

Burger, A.M., Forsyth, J.L., Nicoll, R.S., and Wayne, W.J., 1971, Geologic map of the 1^{o}x2^{o} Muncie quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 5, scale 1:250,000.

Fraser, G.S., 1983, Sand and gravel resources of the Wabash Valley: causes of variability: Indiana Geological Survey Occasional Paper 37, p. 27–42.

Gray, H.H., 1972, Geologic map of the 1^{o}x2^o Louisville quadrangle, Indiana, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 6, scale 1:250,000.

———1984, Surficial geologic map of southern Indiana: Bloomington, Ind., Indiana Geological Survey, unpublished map, scale 1:1,000,000.

Gray, H.H., Bleuer, N.K., Hill, J.R., and Lineback, J.A., 1979, Geologic map of the 1^{o}x2^o Indianapolis quadrangle, Indiana and Illinois, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 1, scale 1:250,000.

Gray, H.H., Forsyth, J.L., Schneider, A.F., and Gooding, A.M., 1972, Geologic map of the 1^{o}x2^o Cincinnati quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 7, scale 1:250,000.

Gray, H.H., Wayne, W.J., and Wier, C.E., 1970, Geologic map of the 1^{o}x2^o Vincennes quadrangle and parts of adjoining quadrangles, Indiana and Illinois, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 3, scale 1:250,000.

Johnson, G.H., and Keller, S.J., 1972, Geologic map of the 1^{o}x2^o Fort Wayne quadrangle, Indiana, Michigan, and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 8, scale 1:250,000.

Lineback, J.A., Bleuer, N.K., Mickelson, D.M., Farrand, W.R., and Goldthwait, R.P., 1983, Quaternary geologic map of the Chicago 4^{o}x6^o quadrangle, United States, in Richmond, G.M., and Fullerton, D.S., eds., Quaternary geologic atlas of the United States: U.S. Geological Survey Miscellaneous Investigations Series Map I–1420 (NK–16), scale 1:1,000,000.

Schneider, A.F., and Keller, S.J., 1970, Geologic map of the 1^{o}x2^o Chicago quadrangle, Indiana, Illinois, and Michigan, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 4, scale 1:250,000.

Wayne, W.J., Johnson, G.H., and Keller, S.J., 1966, Geologic map of the 1^{o}x2^o Danville quadrangle, Indiana and Illinois, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 2, scale 1:250,000.

Thickness Information

Gray, H.H., 1983, Map of Indiana showing thickness of unconsolidated deposits: Indiana Geological Survey Miscellaneous Map 37, scale 1:500,000.

IOWA

Overview of Quaternary deposits.—Surface sediments in Iowa are dominantly silty till, except in southwestern Iowa, where the till is more clayey. Extensive areas of stratified deposits, dominantly coarse grained, are confined to the Missouri and Mississippi River valleys and major tributary valleys. The thickest sediments occur in western Iowa, where 200 to 400 ft of sediment is common, whereas, in central Iowa, thicknesses of 50 to 200 ft are more common. The deposits thin eastward, in part because of postglacial erosion. In eastern Iowa, the sediments are dissected, and bedrock exposures are numerous.

Surficial information.—A 1:1,000,000-scale statewide compilation (Hallberg, 1979) provided a map adequate for compilation of the Quaternary sediments map. More detailed mapping for the

State was not available. The reliability of the data is considered to be moderate.
Thickness information.—Sediment thickness was compiled from a variety of sources, including some thickness maps at scales of 1:250,000 and 1:500,000. Thickness contours for most of the State were constructed by computing sediment thickness from unpublished bedrock topographic and land-surface topographic maps. The reliability of the data is considered to be moderate.
Subsurface information.—The character and geometry of subsurface glacial deposits are not well known in Iowa. In areas of eolian sand or thick (more than 20 ft) loess cover, the character of the underlying sediment was inferred.

Surficial and Stack-Unit Information

Hallberg, G.R. 1979, Quaternary geologic map of Iowa: Iowa City, Iowa Geological Survey, unpublished maps prepared for the Quaternary Geologic Atlas of the United States series (U.S. Geological Survey Miscellaneous Investigations Series Map I–1420), scale 1:1,000,000.

Thickness Information

Anderson, R.R., 1983, Bedrock topography map of Iowa: Iowa City, Iowa Geological Survey Open-File Map, scale 1:250,000. Compiled from the following sources:
Cagle, J.W., 1973, Bedrock topography of south-central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I–763, scale 1:125,000.
Hansen, R.E., 1972, Bedrock topography of east-central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I–717, scale 1:125,000.
———1973, Bedrock topography of southeast Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I–808, scale 1:125,000.
———1975, Bedrock topography of northeast Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I–933, scale 1:125,000.
———1978, Bedrock topography of north-central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I–1080, scale 1:125,000.
———1985, Bedrock topography of central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I–1609, scale 1:125,000.
Munter, J.A., Ludvigson, G.A., and Bunker, B.J., 1983, Hydrogeology and stratigraphy of the Dakota Formation, northwest Iowa: Iowa Geological Survey Water-Supply Bulletin 13, 55 p., scale 1:500,000.
Van Eck, O.J., Anderson, R.R., Black, R.A., and Daut, S.W., 1979, Regional tectonics and seismicity of southwestern Iowa: Iowa Geological Survey Annual Report FY–79 to U.S. Nuclear Regulatory Commission, NUREG/CR–0955, 25 p.
Hallberg, G.R., Anderson, R.R., Reinholtz, P.N., and Pearson, S.G., 1981, Depth to bedrock in northeast Iowa, an isopach of Quaternary deposits: Iowa City, Iowa Geological Survey, scale 1:500,000.
Hoyer, B.E., ed., 1973, Resource development land and water use management, eleven county region, south central Iowa: Iowa Geological Survey Miscellaneous Map Series 4, scale 1:250,000.
Munter, J.A., Ludvigson, G.A., and Bunker, B.J., 1983, Hydrogeology and stratigraphy of the Dakota Formation, northwest Iowa: Iowa Geological Survey Water-Supply Bulletin 13, 55 p., scale 1:500,000.

KANSAS

Overview of Quaternary deposits.—Surface sediments in Kansas are dominantly clayey till. Large areas of surficial stratified deposits, generally coarse grained, are confined to the valleys of the Kansas and Missouri Rivers. These glacial sediments are old, and the deposits are thin where the landscape is dissected; in places, the till cover is patchy, and bedrock or rock residuum exposures are common. Thick surficial deposits are present only in less dissected areas overlying buried preglacial or interglacial valleys.

Surficial information.—A statewide compilation (Denne, 1986), scale 1:1,000,000, provided an adequate map for use in compiling the Quaternary sediments map. Although local, more detailed studies exist for some areas of the State, this map is a modern overview of the surface geology that is well suited to the classification scheme used on the Quaternary sediments map; a reinterpretation of the map was therefore not necessary. The reliability of the data is considered to be moderate.

Thickness information.—A generalized map of sediment thickness was derived from 17 data sources containing well data, cross sections, bedrock topographic maps, and a sediment thickness map of one county. The reliability of the data varies areally depending on the type of data available; overall, the reliability of the data is moderately low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Kansas. In areas of thick (more than 20 ft) loess cover, the character of the underlying sediments was inferred on the Quaternary sediments map.

Surficial and Stack-Unit Information

Bayne, C.K., 1973, Geohydrology of Doniphan County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA–462, scale 1:62,500.

Bayne, C.K., and Schoewe, W.H., 1967, Geology and ground-water resources of Brown County, Kansas: State Geological Survey of Kansas Bulletin 186, 68 p.

*Denne, J.E., 1986, The Quaternary deposits of Kansas: Kansas Geological Survey Geology Series Map 3, scale 1:1,000,000.

Fishel, V.C., 1948, Ground-water resources of the Kansas City, Kansas, area: State Geological Survey of Kansas Bulletin 71, 109 p.

State Geological Survey of Kansas, 1964, Geologic map of Kansas: Lawrence, Kans., scale 1:500,000.

Ward, J.R., 1973, Geohydrology of Atchison County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA–467, scale 1:62,500.

Thickness Information

Bayne, C.K., 1973, Geohydrology of Doniphan County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA–462, scale 1:200,000.

Bayne, C.K., and Schoewe, W.H., 1967, Geology and ground-water resources of Brown County, Kansas: State Geological Survey of Kansas Bulletin 186, 68 p.

Bayne, C.K., and Ward, J.R., 1967, Saturated thickness and specific yield of Cenozoic deposits in Kansas: State Geological Survey of Kansas Map M–5, scale 1:500,000.

Beck, H.V., 1959, Geology and ground-water resources of Kansas River valley between Wamego and Topeka vicinity: State Geological Survey of Kansas Bulletin 135, 88 p.

Davis, S.N., and Carlson, W.A., 1952, Geology and ground-water resources of the Kansas River valley between Lawrence and Topeka, Kansas: State Geological Survey of Kansas Bulletin

96, Part 5, p. 201–276.
Denne, J.E., and Miller, R.E., 1985, Basic data for the hydrogeology and geochemistry of glacial deposits in northeastern Kansas: Kansas Geological Survey Open-File Report 85–10.
Dreeszen, V.H., and Burchett, R.R., 1971, Buried valleys in the lower part of the Missouri River basin, in Pleistocene stratigraphy of Missouri River valley along the Kansas-Missouri border, guidebook for the 20th meeting of the Midwest Friends of the Pleistocene: State Geological Survey of Kansas Special Distribution Publication 53, p. 21–25.
Emmett, L.F., and Jeffery, H.G., 1969, Reconnaissance of the ground-water resources of the Missouri River alluvium between Kansas City, Missouri, and the Iowa border: U.S. Geological Survey Hydrologic Investigations Atlas HA–336, scale 1:125,000.
Fishel, V.C., 1948, Ground-water resources of the Kansas City, Kansas, area: State Geological Survey of Kansas Bulletin 71, 109 p.
Fishel, V.C., and Lohman, S.W., 1948, Ground-water resources of Republic County and northern Cloud County, Kansas: State Geological Survey of Kansas Bulletin 73, 194 p.
Frye, J.C., and Leonard, A.B., 1952, Pleistocene geology of Kansas: State Geological Survey of Kansas Bulletin 99, 230 p.
O'Connor, H.G., 1960, Geology and ground-water resources of Douglas County, Kansas: State Geological Survey of Kansas Bulletin 148, 200 p.
Walters, K.L., 1953, Geology and ground-water resources of Jackson County, Kansas: State Geological Survey of Kansas Bulletin 101, 90 p.
———1954, Geology and ground-water resources of Marshall County, Kansas: State Geological Survey of Kansas Bulletin 106, 116 p.
Walters, K.L., and Bayne, C.K., 1959, Geology and ground-water resources of Clay County, Kansas: State Geological Survey of Kansas Bulletin 136, 106 p.
Ward, J.R., 1973, Geohydrology of Atchison County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA–467, scale 1:190,000.
———1974, Geohydrology of Nemaha County, northeastern Kansas: Kansas Geological Survey Ground Water Series 2, 19 p., scale approx. 1:280,000.

KENTUCKY

Overview of Quaternary deposits.—Glacial ice covered a small area of northern Kentucky for a relatively short time. The glacial deposits that remain on the rugged landscape are relatively old and are thin and highly dissected by modern erosion. In places, they are difficult to distinguish from nonglacial, colluvial material. Glacial and glacially related sediments are dominantly stratified. They are coarse grained in the Ohio River valley and fine grained in tributaries to the Ohio River, which were dammed by glacial outwash in the Ohio River channel.

Surficial information.—The distribution of glacial sediment, largely till, on the uplands was derived from the State geologic map (McDowell and others, 1981). The character of the stratified deposits and the distribution of loess were inferred from the statewide geologic map coverage at 1:24,000 scale. More than 150 geologic maps were used to compile the surface and thickness data. Overall, the reliability of the data and interpretations is considered to be moderate.

Thickness information.—Sediment thickness was derived from geologic unit descriptions on 1:24,000-scale geologic maps and from a limited number of 1:24,000-scale bedrock-surface topographic maps. More than 150 geologic maps were used to compile the surface and thickness data. The reliability of the data is considered to be moderate.

Subsurface information.—The glacial and glacially related deposits in Kentucky are not well described, and their subsurface variability is unknown. In areas of thick loess (more than 20 ft), the character of the underlying sediment was inferred on the Quaternary sediments map.

Surficial, Stack-Unit, and Thickness Information

References for surficial, stack-unit, and thickness mapping are combined into one list to avoid redundancy.

Amos, D.H., 1965, Geology of parts of the Shetlerville and Rosiclare quadrangles, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–400, scale 1:24,000.

———1966, Geologic map of the Golconda quadrangle, Kentucky-Illinois, and the part of the Brownfield quadrangle in Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–546, scale 1:24,000.

———1967, Geologic map of part of the Smithfield quadrangle, Livingston County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–657, scale 1:24,000.

———1970, Geologic map of parts of the Alton and Derby quadrangles, Meade and Breckinridge Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–845, scale 1:24,000.

———1971, Geologic map of part of the Leavenworth quadrangle, Meade County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–941, scale 1:24,000.

———1974, Geologic map of the Burna quadrangle, Livingston County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1150, scale 1:24,000.

Amos, D.H., and Finch, W.I., 1968, Geologic map of the Calvert City quadrangle, Livingston and Marshall Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–731, scale 1:24,000.

Amos, D.H., and Hays, W.H., 1974, Geologic map of the Dycusburg quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1149, scale 1:24,000.

Amos, D.H., and Wolfe, E.W., 1966, Geologic map of the Little Cypress quadrangle, Kentucky-Illinois: U.S. Geological Survey Geologic Quadrangle Map GQ–354, scale 1:24,000.

Baker, L.N., 1963, Geologic map of the New Madrid Southeast and the Hubbard Lake quadrangles in Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–292, scale 1:24,000.

Ball, T.E., 1973, Map showing bedrock topography and subcrop of a selected bed beneath alluvial deposits of part of the Henderson quadrangle, Henderson County, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–812, scale 1:24,000.

Blade, L.V., 1965, Geologic map of the Hickory quadrangle, Graves County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–457, scale 1:24,000.

Calvert, R.H., 1966, Geologic map of the Maceo quadrangle, Daviess and Hancock Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–570, scale 1:24,000.

Carpenter, G.L., Jr., 1971, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of part of the Owensboro West quadrangle, in Daviess County, Kentucky: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–633, scale 1:24,000.

Chaplin, J.R., 1978, Geologic map of the Garrison quadrangle, Kentucky-Ohio, and part of the Pond Run quadrangle, Lewis County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1490, scale 1:24,000.

Dobrovolny, E., Ferm, J.C., and Eroskay, S.O., 1966, Geologic map of parts of the Greenup and Ironton quadrangles, Greenup and Boyd Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–532, scale 1:24,000.

Fairer, G.M., 1973, Geologic map of the Poole quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1088, scale 1:24,000.

———1973, Geologic map of the Robards quadrangle, Henderson and Webster Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1084, scale 1:24,000.
———1975, Geologic map of the Waverly quadrangle, Union and Henderson Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1220, scale 1:24,000.
Fairer, G.M., and Norris, R.L., 1973, Geologic map of the Curdsville quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1039, scale 1:24,000.
Fairer, G.M., Norris, R.L., and Johnson, W.D., Jr., 1975, Geologic map of the Beech Grove quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1230, scale 1:24,000.

Finch, W.I., 1963, Geology of the Water Valley quadrangle in Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–269, scale 1:24,000.
———1964, Geology of the Symsonia quadrangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–326, scale 1:24,000.
———1966, Geologic map of the Paducah West and part of the Metropolis quadrangles, Kentucky-Illinois: U.S. Geological Survey Geologic Quadrangle Map GQ–557, scale 1:24,000.
———1967, Geologic map of part of the Joppa quadrangle, McCracken County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–652, scale 1:24,000.
———1971, Geologic map of part of the Bondurant quadrangle, Fulton County, Kentucky, and New Madrid and Mississippi Counties, Missouri: U.S. Geological Survey Geologic Quadrangle Map GQ–944, scale 1:24,000.
———1971, Geologic map of part of the Hickman quadrangle, Fulton County, Kentucky, and Mississippi County, Missouri: U.S. Geological Survey Geologic Quadrangle Map GQ–874, scale 1:24,000.
Finch, W.I., Olive, W.W., and Wolfe, E.W., 1964, Ancient lake in western Kentucky and southern Illinois: U.S. Geological Survey Professional Paper 501–C, p. C130–C133.
Franklin, G.J., 1965, Geology of the Hanson quadrangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–365, scale 1:24,000.
———1967, Geologic map of the Coiltown quadrangle, Hopkins County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–629, scale 1:24,000.
———1969, Geologic map of the Nebo quadrangle, Webster and Hopkins Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–777, scale 1:24,000.
———1973, Geologic map of the Millport quadrangle, Muhlenberg and Hopkins Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1050, scale 1:24,000.
Gallaher, J.T., 1963, Geology and hydrology of alluvial deposits along the Ohio River in the Hawesville and Cloverport areas, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–72, scale 1:24,000.
———1963, Geology and hydrology of alluvial deposits along the Ohio River in the Lewisport and Owensboro areas, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–74, scale 1:24,000.
———1963, Geology and hydrology of alluvial deposits along the Ohio River in the Spottsville and Reed areas, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–96, scale 1:24,000.
———1964, Geology and hydrology of alluvial deposits along the Ohio River between the Uniontown area and Wickliffe, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–129, scale 1:24,000.

———1964, Geology and hydrology of alluvial deposits along the Ohio River between the Wolf Creek and West Point areas, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–95, scale 1:24,000.
———1964, Geology and hydrology of alluvial deposits along the Ohio River in the Henderson area, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–91, scale 1:24,000.
———1964, Geology and hydrology of alluvial deposits along the Ohio River in the Stanley area, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–110, scale 1:24,000.
Gibbons, A.B., 1972, Geologic map of parts of the Burlington and Addyston quadrangles, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1025, scale 1:24,000.
———1973, Geologic map of parts of the Newport and Withamsville quadrangles, Campbell and Kenton Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1072, scale 1:24,000.
———1975, Geologic map of the Worthville quadrangle, northcentral Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1265, scale 1:24,000.
———1978, Geologic map of part of the Madison East quadrangle, Trimble and Carroll Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1471, scale 1:24,000.
Gibbons, A.B., Kohut, J.J., and Weiss, M.P., 1975, Geologic map of the New Richmond quadrangle, Kentucky-Ohio: U.S. Geological Survey Geologic Quadrangle Map GQ–1228, scale 1:24,000.
Gibbons, A.B., and Weiss, M.P., 1972, Geologic map of the Maysville West quadrangle, Kentucky-Ohio: U.S. Geological Survey Geologic Quadrangle Map GQ–1005, scale 1:24,000.
Goudarzi, G.H., 1968, Geologic map of the Hartford quadrangle, Ohio County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–741, scale 1:24,000.
———1969, Geologic map of the Equality quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–815, scale 1:24,000.
———1971, Geologic map of the Panther quadrangle, Daviess County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–866, scale 1:24,000.
Goudarzi, G.H., and Smith, A.E., 1971, Geologic map of part of the Owensboro West quadrangle, in Daviess County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–890, scale 1:24,000.
Hansen, D.E., 1975, Geologic map of the Sebree quadrangle, Webster County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1238, scale 1:24,000.
———1976, Geologic map of the Dixon quadrangle, Webster County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1293, scale 1:24,000.
———1976, Geologic map of the Sacramento quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1306, scale 1:24,000.
———1978, Geologic map of the Livermore quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1467, scale 1:24,000.
Johnson, W.D., Jr., 1972, Geologic map of parts of the Newburgh and Yankeetown quadrangles, Henderson and Daviess Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1045, scale 1:24,000.
———1972, Geologic map of the Reed quadrangle, Kentucky-Indiana: U.S. Geological Survey Geologic Quadrangle Map GQ–1038, scale 1:24,000.

———1973, Geologic map of part of the Evansville South quadrangle, Henderson County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1089, scale 1:24,000.
———1973, Geologic map of part of the Henderson quadrangle, Henderson County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1074, scale 1:24,000.
———1973, Geologic map of the Delaware quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1087, scale 1:24,000.
———1973, Geologic map of the Spottsville quadrangle, Henderson County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1090, scale 1:24,000.
———1974, Geologic map of part of the Wilson quadrangle, Henderson County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1136, scale 1:24,000.
———1974, Geologic map of parts of the West Franklin, Caborn, and Mount Vernon quadrangles, Henderson and Union Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1152, scale 1:24,000.
———1975, Geologic map of the Calhoun quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1239, scale 1:24,000.
Johnson, W.D., Jr., and Norris, R.L., 1974, Geologic map of the Smith Mills quadrangle, Henderson and Union Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1215, scale 1:24,000.
———1976, Geologic map of the Uniontown and Wabash Island quadrangles, Union and Henderson Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1291, scale 1:24,000.
Johnson, W.D., Jr., and Smith, A.E., 1968, Geologic map of part of the Owensboro East quadrangle, in Daviess County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–751, scale 1:24,000.
———1969, Geologic map of the Sutherland quadrangle, Daviess County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–839, scale 1:24,000.
———1973, Geologic map of the Glenville quadrangle, McLean and Daviess Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1046, scale 1:24,000.
Johnson, W.D., Jr., Smith, A.E., and Fairer, G.M., 1975, Geologic map of the Morganfield quadrangle, Union County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1269, scale 1:24,000.
Kehn, T.M., 1966, Geologic map of the Providence quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–491, scale 1:24,000.
———1968, Geologic map of the Graham quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–765, scale 1:24,000.
———1974, Geologic map of parts of the Dekoven and Saline Mines quadrangles, Crittenden and Union Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1147, scale 1:24,000.
———1974, Geologic map of the Paradise quadrangle, Muhlenberg and Ohio Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1173, scale 1:24,000.
———1975, Geologic map of the Bordley quadrangle, Union and Webster Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1275, scale 1:24,000.
———1975, Geologic map of the Sturgis quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1273, scale 1:24,000.
Kepferle, R.C., 1967, Geologic map of the Colesburg quadrangle, Hardin and Bullitt Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–602, scale 1:24,000.
———1968, Geologic map of the Shepherdsville quadrangle, Bullitt County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–740, scale 1:24,000.

———1972, Geologic map of the Brooks quadrangle, Bullitt and Jefferson Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–961, scale 1:24,000.
———1972, Geologic map of the Valley Station quadrangle, and part of the Kosmosdale quadrangle, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–962, scale 1:24,000.
———1974, Geologic map of parts of the Jeffersonville, New Albany, and Charlestown quadrangles, Kentucky-Indiana: U.S. Geological Survey Geologic Quadrangle Map GQ–1211, scale 1:24,000.
———1974, Geologic map of parts of the Louisville West and Lanesville quadrangles, Jefferson County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1202, scale 1:24,000.
———1974, Geologic map of the Louisville East quadrangle, Jefferson County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1203, scale 1:24,000.
———1977, Geologic map of the Fort Knox quadrangle, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1375, scale 1:24,000.
———1977, Geologic map of the Pitts Point quadrangle, Bullitt and Hardin Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1376, scale 1:24,000.
Lambert, T.W., and MacCary, L.M., 1964, Geology of the Briensburg quadrangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–327, scale 1:24,000.
Lee, K.Y., 1974, Geologic map of the Oakton quadrangle and part of the Wolf Island quadrangle, Hickman and Fulton Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1187, scale 1:24,000.
Luft, S.J., 1969, Geologic map of the Independence quadrangle, Kenton and Boone Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–785, scale 1:24,000.
———1970, Geologic map of the De Mossville quadrangle, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–862, scale 1:24,000.
———1971, Geologic map of part of the Covington quadrangle, northern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–955, scale 1:24,000.
———1972, Geologic map of the Butler quadrangle, Pendleton and Campbell Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–982, scale 1:24,000.
McDowell, R.C., Grabowski, G.J., Jr., and Morse, S.L., 1981, Geologic map of Kentucky: Reston, Va., U.S. Geological Survey, scale 1:250,000.
Moore, F.B., 1977, Geologic map of the Gratz quadrangle, Owen and Henry Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1359, scale 1:24,000.
Moore, S.L., 1974, Geologic map of the South Hill quadrangle, Butler and Ohio Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1180, scale 1:24,000.
Morris, R.H., and Pierce, K.L., 1967, Geologic map of the Vanceburg quadrangle, Kentucky-Ohio: U.S. Geological Survey Geologic Quadrangle Map GQ–598, scale 1:24,000.
Norris, R.L., 1973, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Curdsville quadrangle, western Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–765, scale 1:24,000.
———1973, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Delaware quadrangle, western Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–825, scale 1:24,000.
———1973, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Reed quadrangle, Kentucky-Indiana: U.S. Geological Survey Miscellaneous Investigations Series Map I–802, scale 1:24,000.

———1973, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Spottsville quadrangle, Henderson County, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–814, scale 1:24,000.
———1974, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of parts of the Newburgh and Yankeetown quadrangles, Henderson and Daviess Counties, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–803, scale 1:24,000.
———1974, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of parts of the West Franklin, Caborn, and Mount Vernon quadrangles, Henderson and Union Counties, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–864, scale 1:24,000.
———1975, Map showing bedrock topography and area of occurrence of Madisonville limestone member of Sturgis formation (upper Pennsylvanian) beneath alluvial deposits of the Smith Mills quadrangle, Henderson and Union Counties, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–889, scale 1:24,000.
———1975, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Beech Grove quadrangle, western Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–887, scale 1:24,000.
Olive, W.W., 1963, Geology of the Elva quadrangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–230, scale 1:24,000.
———1966, Geologic map of the Heath quadrangle, McCracken and Ballard Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–561, scale 1:24,000.
———1966, Geologic map of the Paducah East quadrangle, in western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–531, scale 1:24,000.
———1967, Geologic map of part of the Cayce quadrangle, Hickman and Fulton Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–601, scale 1:24,000.
———1969, Geologic map of parts of the Bandana and Olmsted quadrangles, McCracken and Ballard Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–797, scale 1:24,000.
———1971, Geologic map of parts of the Cairo and Barlow quadrangles, Ballard County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–885, scale 1:24,000.
———1971, Geologic map of the Blandville quadrangle, Ballard and Carlisle Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–938, scale 1:24,000.
———1972, Geologic map of the Clinton quadrangle, Hickman County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1030, scale 1:24,000.
———1974, Geologic map of the Wickliffe quadrangle, Kentucky-Missouri, and the part of the Wyatt quadrangle in Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1161, scale 1:24,000.
--———1976, Geologic map of parts of the Arlington and Wickliffe Southwest quadrangles, Carlisle and Hickman Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1329, scale 1:24,000.
Olive, W.W., and Davis, R.W., 1968, Geologic map of the Oak Level quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–744, scale 1:24,000.
Palmer, J.E., 1966, Geologic map of the Dalton quadrangle, western Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–490, scale 1:24,000.
———1972, Geologic map of the Central City East quadrangle, Muhlenberg and Ohio Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1031, scale 1:24,000.

———1976, Geologic map of the Grove Center quadrangle, Kentucky-Illinois, and part of the Shawneetown quadrangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1314, scale 1:24,000.

Peck, J.H., and Pierce, K.L., 1966, Geologic map of part of the Manchester Island quadrangle, Lewis County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–581, scale 1:24,000.

Peterson, W.L., 1966, Geologic map of the Nelsonville quadrangle, central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–564, scale 1:24,000.

———1966, Geologic map of the New Haven quadrangle, Nelson and Larue Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–506, scale 1:24,000.

———1967, Geologic map of the Lebanon Junction quadrangle, central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–603, scale 1:24,000.

Price, W.E., Jr., 1963, Geology and hydrology of alluvial deposits along the Ohio River between South Portsmouth and the Manchester Islands, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–73, scale 1:24,000.

———1964, Geology and hydrology of alluvial deposits along the Ohio River between Catlettsburg and South Portsmouth, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–75, scale 1:24,000.

———1964, Geology and hydrology of alluvial deposits along the Ohio River between Ethridge and the Twelve-mile Island, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–97, scale 1:24,000.

———1964, Geology and hydrology of alluvial deposits along the Ohio River between Newport and Warsaw, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–98, scale 1:24,000.

———1964, Geology and hydrology of alluvial deposits along the Ohio River between Prospect and southwestern Louisville, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–130, scale 1:24,000.

———1964, Geology and hydrology of alluvial deposits along the Ohio River between southwestern Louisville and West Point, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–111, scale 1:24,000.

———1964, Geology and hydrology of alluvial deposits along the Ohio River between the Manchester Islands and Silver Grove, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA–94, scale 1:24,000.

Schilling, F.A., Jr., and Peck, J.H., 1967, Geologic map of the Orangeburg quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–588, scale 1:24,000.

Scott, G.R., and MacCary, L.M., 1968, Geologic map of the Hardin quadrangle, Marshall County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–759, scale 1:24,000.

Seeland, D.A., 1968, Geologic map of part of the Repton quadrangle, in Crittenden County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–754, scale 1:24,000.

Sheppard, R.A., 1964, Geology of the Portsmouth quadrangle, Kentucky-Ohio, and parts of the Wheelersburg and New Boston quadrangles, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–312, scale 1:24,000.

Sims, J.P., 1972, Geologic map of the Dublin quadrangle, Graves and Hickman Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–972, scale 1:24,000.

Smith, A.E., 1969, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Sutherland quadrangle, Daviess County, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–596, scale 1:24,000.

———1971, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Panther quadrangle, Daviess County, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–598, scale 1:24,000.
———1973, Map showing bedrock topography beneath alluvial deposits of the Glenville quadrangle, McLean and Daviess Counties, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–760, scale 1:24,000.
———1975, Map showing bedrock topography beneath alluvial deposits of the Calhoun quadrangle, western Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–906, scale 1:24,000.
———1976, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Grove Center quadrangle and part of the Shawneetown quadrangle, Kentucky-Illinois:U.S. Geological Survey Miscellaneous Investigations Series Map I–954, scale 1:24,000.
———1977, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Sacramento quadrangle, western Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–1036, scale 1:24,000.
———1978, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Livermore quadrangle, western Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–1085, scale 1:24,000.
Smith, A.E., and Ball, T.E., 1973, Map showing bedrock topography and subcrop of selected beds beneath alluvial deposits of the Evansville South quadrangle, Henderson County, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–826, scale 1:24,000.
———1974, Map showing bedrock topography and subcrop of a selected bed beneath alluvial deposits of part of the Wilson quadrangle, Henderson County, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–859, scale 1:24,000.
Smith, A.E., and Norris, R.L., 1976, Map showing bedrock topography and subcrop and area of occurrence of selected beds beneath alluvial deposits of parts of the Uniontown and Wabash Island quadrangles, Union and Henderson Counties, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I–938, scale 1:24,000.
Spencer, F.D., 1964, Geology of parts of the Rockport and Lewisport quadrangles, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–315, scale 1:24,000.
———1964, Geology of the Tell City quadrangle, Kentucky-Indiana: U.S. Geological Survey Geologic Quadrangle Map GQ–356, scale 1:24,000.
Swadley, W C, 1969, Geologic map of parts of the Patriot and Florence quadrangles, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–846, scale 1:24,000.
———1969, Geologic map of the Union quadrangle, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–779, scale 1:24,000.
———1971, Geologic map of part of the Rising Sun quadrangle, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–929, scale 1:24,000.
———1972, Geologic map of parts of the Lawrenceburg, Aurora, and Hooven quadrangles, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–989, scale 1:24,000.
———1973, Geologic map of the Sanders quadrangle, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1095, scale 1:24,000.
———1974, Geologic map of parts of the Vevay South and Vevay North quadrangles, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1123, scale 1:24,000.

———1974, Geologic map of the Glencoe quadrangle, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1154, scale 1:24,000.
———1976, Geologic map of part of the Carrollton quadrangle, Carroll and Trimble Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1281, scale 1:24,000.
———1977, Geologic map of part of the Bethlehem quadrangle, Trimble and Oldham Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1436, scale 1:24,000.
———1977, Geologic map of the Bedford quadrangle, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1409, scale 1:24,000.
———1978, Geologic map of part of the Madison West quadrangle, Trimble County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1469, scale 1:24,000.
Swanson, R.W., 1970, Geologic map of the Melber quadrangle, Graves and McCracken Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–860, scale 1:24,000.
———1978, Geologic map of the La Center quadrangle, Ballard and McCracken Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1417, scale 1:24,000.
Swanson, R.W., and Wilshire, H.G., 1967, Geologic map of the Westplains quadrangle, Graves County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–587, scale 1:24,000.
Trace, R.D., 1974, Geologic map of part of the Cave In Rock quadrangle, Crittenden County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–1201, scale 1:24,000.
Wilshire, H.G., 1963, Geology of the Crutchfield quadrangle in Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–270, scale 1:24,000.

MAINE

Overview of Quaternary deposits.—Surface sediments in Maine are dominantly till, which is more silty in the northern third of the State and more sandy to the south. In northeastern Maine, peat deposits generally less than 20 ft thick are common. Large areas of stratified deposits are more or less confined to the coastal region that was invaded by the sea following retreat of the last ice sheet. In this area, fine-grained sediment predominates, whereas, in low-lying areas elsewhere, coarser grained stratified deposits occur. Outside the area of marine incursion, sediment thickness rarely exceeds 20 ft except in drumlins, and bedrock exposures are numerous in many places. In the southern third of the State, sediment thicknesses between 50 and 100 ft are more common, especially in partly buried glacial valleys both north and south of the marine limit.

Surficial information.—A State surficial geologic map (Thompson and Borns, 1985), scale 1:500,000, was used for the Quaternary sediments map directly without any reinterpretation of map units. The reliability of map data is considered to be high.

Thickness information.—Thickness data were derived from nearly 80 data sources including well-data publications and sediment-thickness maps. The data coverage and reliability are best in the southern third of the State, due to emphasis of mapping in this more densely populated area. The northern part of Maine is sparsely populated; consequently, data on depth to bedrock are sparse. However, the sediment cover is known to be generally thin, so that the lack of data is less significant than if the sediment cover were very thick. Overall, the reliability of the map data is considered to be moderate.

Subsurface information.—In Maine, the variability of glacial deposits in the subsurface is not well known.

Surficial and Stack-Unit Information

Thompson, W.B., and Borns, H.W., Jr., eds., 1985, Surficial geologic map of Maine: Augusta, Maine, Maine Geological Survey, scale 1:500,000.

Thickness Information

Caswell, W.B., Jr., 1974, Physical resources of Knox County, Maine: Maine Geological Survey Physical Resources Series PR–1, scale 1:125,000.

Caswell, W.B., Jr., and Lanctot, E.M., 1975, Ground water resource maps of Lincoln and Sagadahoc Counties: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1975, Ground water resource maps of southern Hancock County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1975, Ground water resource maps of Waldo County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1975, Ground water resource maps of York County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1976, Ground water resource maps of Cumberland County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1976, Ground water resource maps of southern Penobscot County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1976, Ground water resource maps of southern Washington County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1977, Ground water resource maps of Knox County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1977, Ground water resource maps of southern Kennebec County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

———1978, Ground water resource maps of Androscoggin County: Augusta, Maine, Maine Geological Survey, scale 1:250,000.

Caswell, W.B., Jr., Tolman, A.L., and Lanctot, E.M., compilers, 1979 to 1981, Sand and gravel aquifer maps: Augusta, Maine, Maine Geological Survey Open-File Maps, scale 1:50,000.

Knebel, H.J., and Scanlon, K.M., 1985, Maps showing sea-floor topography, depth to bedrock, and sediment thickness, Penobscot Bay, Maine: U.S. Geological Survey Miscellaneous Field Investigations Map MF–1751, scale 1:100,000.

Loiselle, M.C., and Lanctot, E.M., 1982, Shallow land burial area screening study: Augusta, Maine, Maine Geological Survey, 25 p.

Lowell, Thomas, 1980, Evaluation of the mineral potential, upper St. John River valley, Aroostook County, Maine: Maine Geological Survey Open-File 80–14e, 28 p.

Morissey, D.J., 1983, Hydrology of the Little Androscoggin River valley aquifer, Oxford County, Maine: U.S. Geological Survey Water Resources Investigations Report 83–4018, 87 p., scale 1:24,000.

Prescott, G.C., Jr., 1964, Lower Penobscot basin area: U.S. Geological Survey Maine Basic-Data Report no. 2, Ground-Water Series, 40 p.

———1967, Lower Androscoggin River basin area: U.S. Geological Survey Maine Basic-Data Report no. 3, Ground-Water Series, 63 p.

———1968, Lower Kennebec River basin area: U.S. Geological Survey Maine Basic-Data Report no. 4, Ground-Water Series, 38 p.

———1970, Lower Aroostook River basin area: U.S. Geological Survey Maine Basic-Data Report no. 5, Ground-Water Series, 30 p.
———1971, Lower St. John River valley area: U.S. Geological Survey Maine Basic-Data Report no. 6, Ground-Water Series, 22 p.
———1971, Meduxnekeag River-Prestile stream basins area: U.S. Geological Survey Maine Basic-Data Report no. 7, Ground-Water Series, 17 p.
———1973, Southern Washington County area: U.S. Geological Survey Maine Basic-Data Report no. 8, Ground-Water Series, 32 p.
———1976, Windham-Freeport-Portland area: U.S. Geological Survey Maine Basic-Data Report no. 9, Ground-Water Series, 48 p.
———1979, Royal, upper Presumpscot, and upper Saco River basins, Maine: U.S. Geological Survey Maine Hydrologic-Data Report no. 10, Ground-Water Series, 43 p.
Prescott, G.C., Jr., and Drake, J.A., 1962, Southwestern area: U.S. Geological Survey Maine Basic-Data Report no. 1, Ground-Water Series, 35 p.
Tolman, A.L., Tepper, D.H., Prescott, G.C., and Gammon, S.O., 1983, Hydrogeology of significant sand and gravel aquifers, northern York and southern Cumberland Counties, Maine: Maine Geological Survey Open-File 83–1, scale 1:125,000.

Additional Reference

Osberg, P.H., Hussey, A.M., and Boone, G.M., 1985, Bedrock geologic map of Maine: Augusta, Maine, Maine Geological Survey, scale 1:500,000. (Till texture)

MASSACHUSETTS

Overview of Quaternary deposits.—On the upland areas of Massachusetts, surface sediments are dominantly sandy till. These deposits are generally quite thin (less than 20 ft thick), and bedrock exposures are common in places. A compact, silty till more than 20 ft thick is largely confined to drumlins. The eastern third of the State is covered by roughly equal amounts of till and coarse grained stratified sediment. Thick sediment, dominantly coarse grained and stratified, is largely confined to the valleys and coastal areas of the State. In the valleys and coastal areas west of Cape Cod, sediment thicknesses of 50 to 200 ft are common. On Cape Cod and the southern islands, sediment is locally as much as 400 ft thick.

Surficial information.—Map data were compiled directly from unpublished, 1:125,000-scale data (Stone, 1985). This map information portrays the surficial materials and so was readily incorporated into the Quaternary sediments map without the need for reinterpretation. The reliability of the map data is considered to be high.

Thickness information.—An unpublished map (Stone, 1986) of the thickness of surficial materials, scale 1:125,000, was compiled by the author of the unpublished State surficial materials map from numerous well data. The reliability of the map data is considered to be high.

Subsurface information.—The lithology of subsurface units is generally known from well data. Selected buried units were shown diagrammatically on the Quaternary sediments map.

Surficial and Stack-Unit Information

Stone, B.D., 1985, Surficial materials of Massachusetts: Reston, Va., U.S. Geological Survey, unpublished map, scale 1:125,000.

Thickness Information

Stone, B.D., 1986, Thickness of surficial materials in Massachusetts: Reston, Va., U.S. Geological Survey, unpublished maps, scale 1:125,000.

Michigan

Overview of Quaternary deposits.—On Michigan's southern peninsula, the region northwest and west of Saginaw Bay is covered by sandy till and coarse-grained stratified sediment. There, sediment thicknesses commonly range between 400 and 800 ft. In the area south of Saginaw Bay, surface sediments include clayey, silty, and sandy tills and coarse-grained and fine-grained stratified sediment. Thicknesses vary greatly, from less than 50 ft, in places within the lowlands formerly occupied by ice lobes, to 400 ft in the interlobate areas. On Michigan's northern peninsula, sandy till and coarse-grained stratified sediment predominate. In the coastal areas of the northern peninsula, sediment is generally less than 50 ft thick, and bedrock exposures are common in places. Away from the coastal region, along the Wisconsin border, surficial coarse-grained stratified deposits are dominant, and sediments are generally 50 to 200 ft thick.

Surficial information.—Map data were compiled from a statewide compilation (Farrand and Bell, 1982), scale 1:500,000. In some areas, more detailed mapping was used. The reliability of the map data is considered to be moderate.

Thickness information.—For roughly half of the southern peninsula, 36 county maps of sediment thickness provided significant new data to supplement the available statewide thickness map of Passero and others (1981). For the northern peninsula, surficial geologic and topographic maps were used to reinterpret the statewide thickness map. Reliability of map data for the southern peninsula is considered moderate; for the northern peninsula, data reliability is considered to be low.

Subsurface information.—In Michigan, the variability of glacial deposits in the subsurface is not well known.

Surficial and Stack-Unit Information

Chapman, L.J., and Putnam, D.F., 1984, The physiography of southern Ontario (3d ed.): Ontario Geological Survey Special Volume 2, 270 p., scale 1:600,000.

*Farrand, W.R., and Bell, D.L., 1982, Quaternary geology of northern and southern Michigan: Lansing, Mich., Michigan Geological Survey Division, scale 1:500,000.

Hamdy, Y., and Post, L., 1984, An assessment of the Detroit River sediments [abs.]: International Association for Great Lakes Research, 27th Conference on Great Lakes Research, St. Catharines, Ontario, Program, p. 42.

Landtiser, G.R., 1974, Soil survey of St. Clair County, Michigan: Washington, D.C., U.S. Soil Conservation Service, 113 p., scale 1:253,440.

Peterson, W.L., 1985, Surficial geologic map of the Iron River $1^{o}x2^{o}$ quadrangle, Michigan and Wisconsin: U.S. Geological Survey Miscellaneous Investigations Series Map I–1360–C, scale 1:250,000.

Thickness Information

Bricker, D.M., and Milstein, R.L., 1983, Ogemaw County drift thickness: Michigan Geological Survey Division Map 3452 DT, scale 1:63,360.

Cummings, T.R., Twenter, F.R., and Holtschlag, D.J., 1984, Hydrology and land use in Van Buren County, Michigan: U.S. Geological Survey Water-Resources Investigations Report 84–4112, 124 p., scale 1:290,000.

Elowski, R.C., 1981, Mason County drift thickness: Michigan Geological Survey Division Map 3627 DT, scale 1:63,360.

———1982, Newaygo County drift thickness: Michigan Geological Survey Division Map 3581 DT, scale 1:63,360.

———1983, Alcona County drift thickness: Michigan Geological Survey Division Map 3736 DT, scale 1:63,360.

———1983, Crawford County drift thickness: Michigan Geological Survey Division Map 3623 DT, scale 1:63,360.

———1984, Mecosta County drift thickness: Michigan Geological Survey Division Map 3453 DT, scale 1:63,360.

———1984, Montmorency County drift thickness: Michigan Geological Survey Division Map 3747 DT, scale 1:63,360.

———1985, Oceana County drift thickness: Michigan Geological Survey Division Map 3455 DT, scale 1:63,360.

Elowski, R.C., and Bricker, D.M., 1976, Kalkaska County drift thickness: Michigan Geological Survey Division Map 3654 DT, scale 1:63,360.

———1976, Otsego County drift thickness: Michigan Geological Survey Division Map 3764 DT, scale 1:63,360.

Lilienthal, R.T., and Bricker, D.M., 1975, Manistee County drift thickness: Michigan Geological Survey Division Map 3727 DT, scale 1:63,360.

Milstein, R.L., 1981, Clare County drift thickness: Michigan Geological Survey Division Map 3496 DT, scale 1:63,360.

———1981, Missaukee County drift thickness: Michigan Geological Survey Division Map 3564 DT, scale 1:63,360.

———1982, Benzie County drift thickness: Michigan Geological Survey Division Map 3704 DT, scale 1:63,360.

———1982, Lake County drift thickness: Michigan Geological Survey Division Map 3570 DT, scale 1:63,360.

———1982, Osceola County drift thickness: Michigan Geological Survey Division Map 3561 DT, scale 1:63,360.

———1983, Alpena County drift thickness: Michigan Geological Survey Division Map 3745 DT, scale 1:63,360.

———1983, Arenac County drift thickness: Michigan Geological Survey Division Map 3495 DT, scale 1:63,360.

———1983, Bay County drift thickness: Michigan Geological Survey Division Map 3560 DT, scale 1:63,360.

———1983, Charlevoix County drift thickness: Michigan Geological Survey Division Map 3773 DT, scale 1:63,360.

———1983, Gladwin County drift thickness: Michigan Geological Survey Division Map 3440 DT, scale 1:63,360.

———1983, Iosco County drift thickness: Michigan Geological Survey Division Map 3749 DT, scale 1:63,360.

———1984, Emmet County drift thickness: Michigan Geological Survey Division Map 3717 DT, scale 1:63,360.

———1984, Midland County drift thickness: Michigan Geological Survey Division Map 3494 DT, scale 1:63,360.

Monahan, G.W., Larson, G.J., Forstat, D.W., and Sorensen, H.O., 1983, Selected geologic maps of Kalamazoo County, Michigan: Michigan Geological Survey Division County Geologic Map Series—Kalamazoo, scale 1:100,000.
Mozola, A.J., and Smith, E.I., 1967, Glacial drift thickness map of Wayne County, Michigan: Michigan Geological Survey Division Map 3664 DT, scale 1:63,360.
Ostrander, A.G., 1978, Cheboygan County drift thickness: Michigan Geological Survey Division Map 3771 DT, scale 1:63,360.
Passero, R.N., Straw, W.T., and Schmaltz, L.J., project directors, 1981, Hydrogeologic atlas of Michigan: Kalamazoo, Mich., Western Michigan University, Department of Geology, scale 1:500,000.
Puzio, M.C., Larson, G.J., Rieck, R.L., Forstat, D.W., and Sorensen, H.O., 1983, Selected geologic maps of Allegan County, Michigan: Michigan Geological Survey Division County Geologic Map Series—Allegan, scale 1:100,000.
———1983, Selected geologic maps of Ingham County, Michigan: Michigan Geological Survey Division County Geologic Map Series—Ingham, scale 1:100,000.
Reszka, C.R., 1976, Grand Traverse County drift thickness: Michigan Geological Survey Division Map 3772 DT, scale 1:63,360.
———1983, Antrim County drift thickness: Michigan Geological Survey Division Map 3767 DT, scale 1:63,360.
———1983, Roscommon County drift thickness: Michigan Geological Survey Division Map 3555 DT, scale 1:63,360.
———1983, Wexford County drift thickness: Michigan Geological Survey Division Map 3714 DT, scale 1:63,360.
———1984, Isabella County drift thickness: Michigan Geological Survey Division Map 3477 DT, scale 1:63,360.
———1984, Oscoda County drift thickness: Michigan Geological Survey Division Map 3744 DT, scale 1:63,360.

MINNESOTA

Overview of Quaternary deposits.—Surface sediments in Minnesota are dominantly silty till; areas of sandy till are confined to the northeast, near Lake Superior. The largest areas of surficial coarse-grained stratified deposits are between lobes fringing the ice lobe basin west of Lake Superior and along the margins of glacial Lake Agassiz, in the valley of the Red River, northwest Minnesota. Most areas of fine-grained stratified deposits are confined to the basin of glacial Lake Agassiz. In the northern quarter of the State, a veneer of peat and fine-grained sediment overlies till. The thickest sediment occurs in central and western Minnesota, where thicknesses of 200 to 400 ft are common. To the northeast, the sediments are thin and bedrock exposures are common. To the southeast, the landscape is dissected, the glacial deposits are thin and relatively old, and exposures of bedrock and rock residuum are numerous.

Surficial information.—The Quaternary sediments map was compiled largely from a statewide map (Hobbs and Goebel, 1982), scale 1:500,000. A moderate amount of reinterpretation was required, because the map units are not directly equivalent to map units in the classification scheme used for the Quaternary sediments map. In places, more detailed geologic maps were used to aid reinterpretation. Overall, the reliability of the map data is considered to be moderate.

Thickness information.—Thickness data were compiled from a statewide map (Olsen and Mossler, 1982), scale 1:1,000,000, and unpublished data. Extensive interpolation of data was required for most of central Minnesota, where data are sparse and sediment thicknesses are generally 200 to 400 ft. The reliability of map data is considered to be moderately low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not generally known in Minnesota. However, the general extent of major buried aquifers (from Kanivetsky, 1979) was shown diagrammatically on the Quaternary sediments map.

Surficial and Stack-Unit Information

*Hobbs, H.C., and Goebel, J.E., 1982, Geologic map of Minnesota, Quaternary geology: Minnesota Geological Survey State Map Series S–1, scale 1:500,000.

Kanivetsky, Roman, 1979, Hydrogeologic map of Minnesota, Quaternary hydrogeology: Minnesota Geological Survey State Map Series S–3, scale 1:500,000.

Leverett, Frank, 1932, Quaternary geology of Minnesota and parts of adjacent States: U.S. Geological Survey Professional Paper 161, 149 p., scale 1:62,500.

Thickness Information

Minnesota Geological Survey, unpublished well logs.

*Olsen, B.M., and Mossler, J.H., 1982, Geologic map of Minnesota, depth to bedrock: Minnesota Geological Survey State Map Series S–14, scale 1:1,000,000.

MISSOURI

Overview of Quaternary deposits.—Surface sediments in Missouri are dominantly clayey till. The till deposits are relatively old and dissected. Large areas of stratified sediment, generally coarse grained, are confined to the valleys of the Missouri and Mississippi Rivers and major tributaries. Sediment thicknesses are greatest, commonly between 100 and 200 ft, on the less dissected areas of the uplands. Thicknesses decrease from north to south, toward the glacial margin, as dissection and the relative area of bedrock exposure increase.

Surficial information.—The Quaternary sediments map was compiled from a statewide surficial materials map (Whitfield, 1982), scale 1:1,100,000, supplemented by unpublished data. A moderate amount of reinterpretation was required. The reliability of the map data is considered to be moderately low.

Thickness information.—A highly generalized statewide compilation (Stohr and others, 1981), scale 1:500,000, served as the basis for compilation of thickness data for the Quaternary sediments map. Cross sections, well data, bedrock-surface and land-surface topographic maps, and surficial geologic information were used to reinterpret the thickness data shown on the statewide compilation. The reliability of the map data is considered to be low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Missouri. However, in a few places, subsurface units were depicted diagrammatically on the Quaternary sediments map. For example, in areas of thick loess (more than 20 ft), the lithology of the underlying unit was inferred.

Surficial Information

Whitfield, J.W., 1982, Surficial materials map of Missouri: Rolla, Mo., Missouri Division of Geology and Land Survey, scale approx. 1:1,100,000.

Thickness Information

Emmett, L.F., and Jeffery, H.G., 1968, Reconnaissance of the ground-water resources of the Missouri River alluvium between St. Charles and Jefferson City, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA–315, scale 1:125,000.

———1969, Reconnaissance of the ground-water resources of the Missouri River alluvium between Jefferson City and Miami, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA–340, scale 1:125,000.

———1969, Reconnaissance of the ground-water resources of the Missouri River alluvium between Kansas City, Missouri, and the Iowa border: U.S. Geological Survey Hydrologic Investigations Atlas HA–336, scale 1:125,000.

———1970, Reconnaissance of the ground-water resources of the Missouri River alluvium between Miami and Kansas City, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA–344, scale 1:125,000.

Gann, E.E., Harvey, E.J., Barks, J.H., and Fuller, D.L., 1973, Water resources of northwestern Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA–444, 4 sheets.

Gann, E.E., Harvey, E.J., Jeffery, H.G., and Fuller, D.L., 1971, Water resources of northeastern Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA–372, 4 sheets.

Heim, G.E., and Howe, W.B., 1962, Map of bedrock topography of northwestern Missouri, in Groundwater maps of Missouri: Rolla, Mo., Missouri Division of Geological Survey and Water Resources, scale 1:300,000.

*Stohr, C.J., St. Ivany, Gary, and Williams, J.H., 1981, Geologic aspects of hazardous-waste isolation in Missouri: Missouri Division of Geology and Land Survey Engineering Geology Report 6, 55 p., scale 1:500,000.

U.S. Geological Survey and Missouri Division of Geological Survey and Water Resources, 1967, Mineral and water resources of Missouri: U.S. Congress, 90th, 1st sess., Senate Doc. 19 (Missouri Division of Geological Survey and Water Resources [Report], 2d ser., v. 43), 399 p.

MONTANA

Overview of Quaternary deposits.—This report includes only the continentally glaciated portion of Montana that lies east of the Rocky Mountains. Surface sediments are dominantly silty or clayey till, except in easternmost Montana, where the till is more sandy. Large areas of surficial stratified sediment, dominantly coarse grained, are confined to the valleys of major rivers, including the Missouri and Milk Rivers. Sediment thickness is generally less than 50 ft, except over preglacial or interglacial buried valleys, where thicknesses between 50 and 200 ft are common. In northeastern Montana, more than 400 ft of sediment is known to fill buried valleys. Near the glacial margin and on many areas of the glaciated uplands, the till cover is patchy and bedrock exposures are numerous. The numerous glacial lake basins adjacent to the glacial margin, formerly mapped as areas of stratified deposits with bedrock exposures, contain virtually no glacial deposits.

Surficial information.—The character of the surficial deposits has been mapped in only a few areas. For the Quaternary sediments map, the surface sediments information was compiled by interpreting geologic data from 38 publications, ranging from 1:24,000-scale geologic maps to reconnaissance soil surveys. Much of the mapped area in Montana was not covered by these publications. The reliability of the map data therefore must be considered low.

Thickness information.—Thickness data for the Montana part of the Quaternary sediments map were compiled directly from a previous compilation (Bergantino, unpub. map, 1976), scale 1:1,000,000. That map is considered to be reasonably accurate for that scale. Given the great amount of territory that is largely unmapped, the source map's small scale is appropriate. The reliability of the map data is considered to be moderately low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Montana. However, on the Quaternary sediments map, the locations of some buried aquifers in the major buried channels are shown diagrammatically.

Surficial and Stack-Unit Information

Alden, W.C., 1932, Physiography and glacial geology of eastern Montana and adjacent areas: U.S. Geological Survey Professional Paper 174, 133 p., scale 1:500,000.

Alverson, D.C., 1965, Geology and hydrology of the Fort Belknap Indian Reservation, Montana: U.S. Geological Survey Water-Supply Paper 1576–F, 59 p., scale 1:62,500.

Bingham, L.C., Daniels, L.A., Smith, J.H., and Koehler, M.J., 1984, Soil survey of Valley County, Montana: Washington, D.C., U.S. Soil Conservation Service, 102 p., scale 1:570,240.

Clark, C.O., Farnsworth, D.H., Miller, F.T., and Weight, B.N., 1982, Soil survey of Cascade County area, Montana: Washington, D.C., U.S. Soil Conservation Service, 329 p., scale 1:506,880.

Collier, A.J., and Knechtel, M.M., 1939, The coal resources of McCone County, Montana: U.S. Geological Survey Bulletin 905, 80 p.

Colton, R.B., Lemke, R.W., and Lindvall, R.M., 1961, Glacial map of Montana east of the Rocky Mountains: U.S. Geological Survey Miscellaneous Investigations Series Map I–327, scale 1:500,000.

Fisher, C.A., 1909, Geology of the Great Falls coal field, Montana: U.S. Geological Survey Bulletin 356, 85 p., scale 1:125,000.

Gieseker, L.F., Morris, E.R., Strahorn, A.T., and Manifold, C.B., 1929, Soil survey (reconnaissance) of the northern plains of Montana: Washington, D.C., U.S. Soil Conservation Service, 74 p., scale 1:500,000.

Haigh, J.G., Tarrell, R.D., Parcell, J.T., Hunter, H.E., and others, 1980, Soil survey of Glacier County area and part of Pondera County, Montana: Washington, D.C., U.S. Soil Conservation Service, 161 p., scale 1:506,880.

Hilts, G.B., 1976, Advance sheet of general soil map of Blaine County, Montana: Bozeman, Mont., U.S. Soil Conservation Service, scale 1:500,000.

———1985, Advance sheet of general soil map of Choteau-Conrad area, parts of Teton and Pondera Counties, Montana: Bozeman, Mont., U.S. Soil Conservation Service, scale approx. 1:500,000.

Holder, T.J., and Pescador, Pedro, Jr., 1976, Soil survey of Dawson County, Montana: Washington, D.C., U.S. Soil Conservation Service, 72 p., scale 1:380,160.

Kerr, J.H., Pecora, W.T., Stewart, D.B., and Dixon, H.R., 1957, Preliminary geologic map of the Shambo quadrangle, Bearpaw Mountains, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I–236, scale 1:31,680.

Lemke, R.W., 1977, Geologic map of the Great Falls quadrangle, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–1414, scale 1:62,500.

Lindvall, R.M., 1953, Geologic map of the Eagleton quadrangle, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–29, scale 1:62,500.

———1956, Geology of the Big Sandy quadrangle, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–130, scale 1:62,500.
———1956, Geology of the Kenilworth quadrangle, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–129, scale 1:62,500.
———1961, Geology of the Boxelder quadrangle, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–338, scale 1:62,500.
———1962, Geology of the Eagle Buttes quadrangle, Choteau County, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–349, scale 1:62,500.
———1962, Geology of the Eskay quadrangle, Choteau and Blaine Counties, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–353, scale 1:62,500.
Maughan, E.K., 1961, Geologic map of the Vaughn quadrangle, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–135, scale 1:62,500.
Pecora, W.T., Witkind, I.J., and Stewart, D.B., 1957, Preliminary general geologic map of the Laredo quadrangle, Bearpaw Mountains, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–234, scale 1:31,680.
Pescado, Pedro, Jr., and Brockmann, L.C., 1980, Soil survey of Richland County, Montana: Washington, D.C., U.S. Soil Conservation Service, 71 p., scale 1:443,520.
Pritchard, G.E., and Landis, E.R., 1975, Coal resources and Cenozoic geology of the Girard coal field, Richland County, Montana: U.S. Geological Survey Bulletin 1310, 89 p., scale 1:62,500.
Schmidt, R.G., Pecora, W.T., Bryant, Bruce, and Ernst, W.G., 1960, Geology of the Lloyd quadrangle, Bearpaw Mountains, Blaine County, Montana: U.S. Geological Survey Bulletin 1081–E, p. 159–188, scale 1:31,680.
Schmidt, R.G., Pecora, W.T., and Hearn, B.C., Jr., 1964, Geology of the Cleveland quadrangle, Bearpaw Mountains, Blaine County, Montana: U.S. Geological Survey Bulletin 1141–P, 26 p., scale 1:31,680.
Smith, J.F., Jr., Witkind, I.J., and Trimble, D.E., 1959, Geology of the lower Marias River area, Choteau, Hill, and Liberty Counties, Montana: U.S. Geological Survey Bulletin 1071–E, p. 121–155, scale 1:62,500.
Stewart, D.B., Pecora, W.T., Engstrom, D.B., and Dixon, H.R., 1957, Preliminary geologic map of the Centennial Mountain quadrangle, Bearpaw Mountains, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–235, scale 1:31,680.
Strom, D.E., 1984, Soil survey of McCone County, Montana: Washington, D.C., U.S. Soil Conservation Service, 361 p., scale 1:506,880.
Svendsen, N.R., 1985, Advance sheet of general soil map of Choteau County, Montana: Bozeman, Mont., U.S. Soil Conservation Service, scale 1:500,000.
Swenson, F.A., 1955, Geology and ground-water resources of the Missouri River valley in northeastern Montana: U.S. Geological Survey Water-Supply Paper 1263, 128 p., scale 1:96,000.
———1957, Geology and ground-water resources of the lower Marias irrigation project, Montana: U.S. Geological Survey Water-Supply Paper 1460–B, 98 p., scale 1:96,000.
Torry, A.E., and Kohout, F.A., 1956, Geology and ground-water resources of the lower Yellowstone River valley, between Glendive and Sidney, Montana: U.S. Geological Survey Water-Supply Paper 1355, 92 p., scale 1:125,000.
U.S. Bureau of Land Management, 1978, Unpublished soil maps of parts of Philips County, Montana: Malta, Mont., U.S. Bureau of Land Management, scales 1:63,360 and 1:126,720.

Van Lewen, M.C., and King, N.J., 1971, Prospects for developing stock-water supplies from wells in northeastern Garfield County, Montana: U.S. Geological Survey Water-Supply Paper 1999–F, 38 p., scale 1:125,000.
Weed, W.H., 1899, Description of the Fort Benton quadrangle [Montana]: U.S. Geological Survey Geologic Atlas, Folio 55, scale 1:250,000.
Zimmerman, E.A., 1960, Preliminary report on the geology and ground-water resources of northern Blaine County, Montana: Montana Bureau of Mines and Geology Bulletin 19, 19 p., scale 1:125,000.

Thickness Information

Bergantino, R.N., 1976, Thickness of unconsolidated deposits in Montana, a preliminary map: Butte, Mont., Montana Bureau of Mines and Geology, unpublished map, scale 1:1,000,000.

Additional Reference

Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: Washington, D.C., U.S. Geological Survey, scale 1:500,000. (Till texture)

NEBRASKA

Overview of Quaternary deposits.—Surface sediments in Nebraska are dominantly clayey till. Large areas of stratified deposits, generally coarse grained, occur in the valleys of the Missouri and Platte Rivers and along the western margin of glaciation. Sediment thickness is greatest in the north and west, where 100 to 200 ft of sediment is common. To the south and east toward the Missouri River, the deposits are thinner and, in places, are less than 50 ft thick. To the west, in the extensive area of stratified sediment, thicknesses of 200 to 400 ft are common on the uplands away from major valleys such as the Platte.

Surficial information.—The character of surface sediments as shown on the Quaternary sediments map was derived from geologic and soil maps ranging in scale from 1:190,080 to 1:1,000,000. Extensive interpretation was required, especially for the soil maps, because map units rarely were compatible with the map units used on the Quaternary sediments map. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from thickness maps and from thicknesses computed by comparison of bedrock-surface and land-surface topographic maps. Reliability of the map data is considered to be moderate.

Subsurface information.—Although the character and geometry of the subsurface glacial deposits are not well known, the general location of till buried by stratified deposits along the western margin of glaciation is shown diagrammatically. The location of thick loess (more than 20 ft) and the inferred lithology of the underlying deposits also are shown.

Surficial, Stack-Unit, and Thickness Information

References for surficial, stack-unit, and thickness mapping are combined into one list to avoid redundancy.

Boellstorff, J.D., and Swinehart, J.B., 1981, Quaternary map of Nebraska: Nebraska Conservation and Survey Division, unpublished map prepared for the U.S. Geological Survey's Quaternary Geologic Atlas of the United States (Miscellaneous Investigations Series Map I–1420), scale 1:1,000,000.
Burchett, R.R., Dreeszen, V.H., Reed, E.C., and Prichard, G.E., 1972, Bedrock geologic map showing thickness of overlying Quaternary deposits, Lincoln quadrangle and part of Nebraska City quadrangle, Nebraska and Kansas: U.S. Geological Survey Miscellaneous Investigations Series Map I–729, scale 1:250,000.
Burchett, R.R., Dreeszen, V.H., Souders, V.L., and Prichard, G.E., 1988, Bedrock geologic map showing configuration of the bedrock surface in the Nebraska part of the Sioux City 1^{o}x2^{o} quadrangle: U.S. Geological Survey Miscellaneous Investigations Series Map I–1879, scale 1:250,000.
Burchett, R.R., Reed, E.C., Dreeszen, V.H., and Prichard, G.E., 1975, Bedrock geologic map showing thickness of overlying Quaternary deposits, Fremont quadrangle and part of Omaha quadrangle, Nebraska: U.S. Geological Survey Miscellaneous Investigations Series Map I–905, scale 1:250,000.
Dreeszen, V.H., 1970, The stratigraphic framework of Pleistocene glacial and periglacial deposits in the central plains, in Dort, Wakefield, Jr., and Jones, J.K., Jr., eds., Pleistocene and Recent environments of the central Great Plains: Kansas University Department of Geology, Special Publication 3, p. 9–22, scale 1:1,500,000.
Flint, R.F. (committee chairman), 1959, Glacial map of the United States east of the Rocky Mountains: New York, Geological Society of America, scale 1:1,750,000.
Kerl, D.E., 1982, Soil survey of Butler County, Nebraska: Washington, D.C., U.S. Soil Conservation Service, 198 p., scale 1:190,080.
Kollmorgen, H.L., 1963, Isopachous map and study on thickness of Peorian loess in Nebraska: Soil Science Society of America Proceedings, v. 27, p. 445–448.
Kollmorgen, H.L., and Reed, E.C., 1981, Distribution and thickness of Peoria Loess (Wisconsinan) in Nebraska: Lincoln, Neb., Nebraska Conservation and Survey Division, unpublished map, scale 1:1,000,000.
Quandt, L.A., James, Melvin, and Good, Kenneth, 1974, Soil survey of Seward County, Nebraska: Washington, D.C., U.S. Soil Conservation Service, 85 p., scale 1:190,080.
Schultz, C.B., and Smith, H.T.U., eds., 1965, Central Great Plains: International Association for Quaternary Research, 7th Congress, INQUA field conference D, Guidebook, 128 p.
U.S. Soil Conservation Service and Nebraska Conservation and Survey Division, 1980, General soil map of Fremont area— Nebraska: Lincoln, Neb., University of Nebraska, scale 1:250,000.
———1980, General soil map of Lincoln area—Nebraska: Lincoln, Neb., University of Nebraska, scale 1:250,000.
———1980, General soil map of Sioux City area—Nebraska: Lincoln, Neb., University of Nebraska, scale 1:250,000.

NEW HAMPSHIRE

Overview of Quaternary deposits.—Surface sediments in New Hampshire are dominantly sandy till. Large areas of coarse-grained stratified deposits occur in the Merrimack and Connecticut River valleys and major tributaries and in coastal New Hampshire. Fine-grained stratified deposits also are extensive in coastal New Hampshire and in the Connecticut River valley. On the uplands, where till is the dominant surficial deposit, sediment thicknesses generally do not exceed 50 ft, and, in areas of high relief including the White Mountains, the till cover is patchy and bedrock exposures are numerous. Thick sediments are confined to the river valleys, where stratified sediments may reach 100 ft or more in thickness.

Surficial information.—The Quaternary sediments map was compiled from 20 surficial geologic and soil maps, mostly at scales of 1:62,500 or larger. The surficial geologic map coverage is quite limited, and extensive interpretation of all available data was required. The reliability of the map data is considered to be moderately low.

Thickness information.—Sediment thickness and bedrock topography have not been mapped in New Hampshire, and so the Quaternary sediments map was compiled from well data only. The well data are concentrated in the more populous southern third of the State; throughout the State, well-data coverage permitted only a generalized interpretation of the thickness distribution. Overall, the reliability of map data therefore is considered to be low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in New Hampshire. For the Quaternary sediments map, this lack of data was relatively insignificant because of the thinness of the glacial sediment throughout the State. In a few areas of stratified sediment, the character of buried units is shown diagrammatically.

Surficial and Stack-Unit Information

Bradley, E., 1964, Geology and ground-water resources of southeastern New Hampshire: U.S. Geological Survey Water-Supply Paper 1695, 80 p., scale approx. 1:62,000.

Castle, R.O., 1958, Surficial geology of the Lawrence quadrangle, Massachusetts-New Hampshire: U.S. Geological Survey Geologic Quadrangle Map GQ–107, scale 1:31,680.

Denny, C.S., 1958, Surficial geology of the Canaan area, New Hampshire: U.S. Geological Survey Bulletin 1061–C, p. 73–101, scale 1:62,500.

Diers, R.W., Vieira, F.J., Douglas, W.W., Winkelaar, P.W., and Eagleston, D., 1977, Soil survey of Carroll County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 161 p., scale 1:24,000.

Goldthwait, J.W., 1950, Surficial geology of New Hampshire: Concord, N.H., New Hampshire State Planning and Development Commission, scale 1:250,000.

Goldthwait, Lawrence, 1953, Clays of southeastern New Hampshire, a preliminary report: New Hampshire State Planning and Development Commission, Mineral Resource Survey, pt. 15, p. 1–13. scale approx. 1:130,000.

Goldthwait, R.P., 1968, Surficial geology of the Wolfeboro-Winnipesaukee area, New Hampshire: Durham, N.H., New Hampshire Department of Resources and Economic Development, 54 p., scale 1:62,500.

Kelsey, T.L., Vieira, F.J., Winkley, H.E., and Van der Voet, D., 1968, Soil survey of Belknap County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 68 p., scale 1:15,840.

Koteff, Carl, 1970, Surficial geologic map of the Milford quadrangle, Hillsborough County, New Hampshire: U.S. Geological Survey Geologic Quadrangle Map GQ–881, scale 1:62,500.

———1976, Surficial geologic map of the Nashua North quadrangle, Hillsborough and Rockingham Counties, New Hampshire: U.S. Geological Survey Geologic Quadrangle Map GQ–1290, scale 1:24,000.

Koteff, Carl, and Volckmann, R.P., 1973, Surficial geologic map of the Pepperell quadrangle, Middlesex County, Massachusetts, and Hillsborough County, New Hampshire: U.S. Geological Survey Geologic Quadrangle Map GQ–1118, scale 1:24,000.

Latimer, W.J., Layton, M.H., Lyford, W.H., Coates, W.H., and Scripture, P.N., 1935, Soil survey of Grafton County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 79 p., scale 1:62,500.

Mooney, C.N., Westover, H.L., and Bennett, F., 1908, Soil survey of Merrimack County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 39 p., scale 1:63,360.
Newton, R.M., 1974, Surficial geology of the Ossipee Lake quadrangle, New Hampshire: Durham, N.H., New Hampshire Department of Resources and Economic Development, 47 p., scale 1:62,500.
Shearin, A.E., Williams, B.H., Gladwin, F.J., Howard, M., and Coates, W.H., 1940, Soil survey of Strafford County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 141 p., scale 1:31,680.
Simmons, C.S., Latimer, W.J., Layton, M.H., Coates, W.H., Lyford, W.H., and Scripture, P.N., 1937, Soil survey of Cheshire and Sullivan Counties, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 82 p., scale 1:62,500.
Simmons, C.S., Lyford, W.H., and Feuer, R., 1940, Soil survey of Hillsborough County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 114 p., scale 1:63,360.
Van der Voet, D., Shearin, A.E., Bailey, H., Carter, W.J., and others, 1959, Soil survey of Rockingham County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 78 p., scale 1:20,000.
Williams, B.H., Coates, W.H., and Scripture, P.N., 1937, Soil survey of Coos County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 99 p., scale 1:62,500.
Winkley, H.E., Van der Voet, D., Vieira, F.J., Hutchinson, E.F., and others, 1965, Soil survey of Merrimack County, New Hampshire: Washington, D.C., U.S. Soil Conservation Service, 94 p., scale 1:20,000.

Thickness Information

Antevs, E., 1922, The recession of the last ice sheet in New England: American Geographic Society Research Series no. 11, 120 p.
Bradley, Edward, and Petersen, R.G., 1962, Southeastern area: U.S. Geological Survey New Hampshire Basic-Data Report no. 1, Ground-Water Series, 53 p.
Cotton, J.E., 1974–77, Ground water availability maps for the nine river basins of New Hampshire: U.S. Geological Survey Water Resources Investigations Reports 39–74, 22–75, 47–75, 53–75, 76–18, 76–39, 77–69, 77–70, 77–79, scale 1:125,000.
Goldthwait, J.W., ca. 1944, unpublished records of well data for New Hampshire: Durham, N.H., Office of the New Hampshire State Geologist.
Goldthwait, R.P., 1949, Artesian wells in New Hampshire: New Hampshire State Planning and Development Commission, Mineral Resource Survey, pt. 11, 24 p.
Hitchcock, C.H., and Upham, W., 1878, The geology of New Hampshire, part III. Surface geology: Durham, N.H., New Hampshire Geological Survey, 340 p.
Koteff, Carl, 1976, Surficial geologic map of the Nashua North quadrangle, Hillsborough and Rockingham Counties, New Hampshire: U.S. Geological Survey Geologic Quadrangle Map GQ–1290, scale 1:24,000.
Weigle, J.M., and Kranes, Richard, 1966, Lower Merrimack River valley: U.S. Geological Survey New Hampshire Basic-Data Report no. 2 (open file), 44 p.
Whitcomb, H.A., 1973, Hydrologic data of the Ashuelot River basin, New Hampshire: U.S. Geological Survey New Hampshire Hydrologic-Data Report no. 3 (open file), 25 p.

NEW JERSEY

Overview of Quaternary deposits.—Surface sediments in New Jersey are dominantly sandy till. Coarse-grained stratified deposits are confined to river valleys, and fine-grained stratified deposits occur in glacial lake basins in northeastern New Jersey. Sediment thickness is generally less than 50 ft on the uplands. In the highlands of north-central New Jersey, the till cover is patchy and bedrock exposures are numerous. Thicker sediments, generally 50 to 100 ft, are confined to buried valleys and beneath the end moraine of the last glaciation. Beyond the end moraine, the older glacial sediment is patchy and in places is colluviated.

Surficial information.—The Quaternary sediments map was compiled from seven publications, two unpublished maps, and several written communications. Much of the data was taken from high-quality USGS geologic mapping circa 1900. Substantial revision was necessary to adapt data to the classification scheme of the Quaternary sediments map. The reliability of the map data is considered to be moderately high.

Thickness information.—Thickness data for the New Jersey part of the Quaternary sediments map were compiled directly from an unpublished map (Harper, 1986), scale 1:250,000. The reliability of the map data is considered to be moderately high.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in New Jersey. In places, the lithology of units underlying the thin peat deposits was inferred.

Surficial and Stack-Unit Information

Bayley, W.S., Salisbury, R.D., and K_mmel, H.B., 1914, Description of the Raritan quadrangle [New Jersey]: U.S. Geological Survey Geologic Atlas, Folio 191, scale 1:125,000.

Darton, N.H., Bayley, W.S., Salisbury, R.D., and K_mmel, H.B., 1908, Description of the Passaic quadrangle [New Jersey-New York]: U.S. Geological Survey Geologic Atlas, Folio 157, scale 1:125,000.

Harper, D.P., 1982, Late Wisconsinan glacial geology, New Jersey: Trenton, N.J., New Jersey Geological Survey, unpublished map, scale 1:250,000.

———1986, Thickness of unconsolidated deposits in northern New Jersey: Trenton, N.J., New Jersey Geological Survey, unpublished map, scale 1:250,000.

Merrill, F.J.H., Darton, N.H., Hollick, Arthur, Salisbury, R.D., and others, 1902, Description of the New York City district [New York-New Jersey]: U.S. Geological Survey Geologic Atlas, Folio 83, scale 1:62,500.

Owens, J.P., and Minard, J.P., 1975, Geologic map of the surficial deposits in the Trenton area, New Jersey and Pennsylvania: U.S. Geological Survey Miscellaneous Investigations Series Map I–884, scale 1:48,000.

Parker, G.G., Hely, A.G., Keighton, W.B., Olmsted, F.H., and others, 1964, Water resources of the Delaware River basin: U.S. Geological Survey Professional Paper 381, 200 p., scale 1:500,000.

Salisbury, R.D., K_mmel, H.B., Peet, C.E., and Knapp, G.N., 1902, The glacial geology of New Jersey: Trenton, N.J., New Jersey Geological Survey, Final Report of the State Geologist, v. 5, 802 p., scale 1:316,800.

Spencer, A.C., K_mmel, H.B., Wolff, J.E., Salisbury, R.D., and Palache, Charles, 1908, Description of the Franklin Furnace quadrangle [New Jersey]: U.S. Geological Survey Geologic Atlas, Folio 161, scale 1:62,500.

Thickness Information

Harper, D.P., 1986, Thickness of unconsolidated deposits in northern New Jersey: Trenton, N.J., New Jersey Geological Survey, unpublished map, scale 1:250,000.

NEW YORK

Overview of Quaternary deposits.—Surface sediments in New York are dominantly silty till, except in the Adirondack and Catskill Mountains, where the till is more sandy. Large areas of stratified deposits, mostly coarse grained, occur in major valleys throughout the State and on Long Island. Fine-grained stratified deposits are extensive in the Lake Champlain and Lake Ontario lowlands and in the Hudson River valley. On the uplands, sediment thicknesses are generally less than 50 ft; in mountainous areas, the till is patchy and bedrock exposures are common. Thick sediment is confined to Long Island and to river valleys. In the river valleys of upstate New York and for all of Long Island, thicknesses of stratified deposits are commonly 50 to 400 ft and in some valleys are as much as 600 ft. Here, upstate New York refers to all areas of the State except Long Island.

Surficial information.—A surficial geologic map of the State did not exist, and so more than 60 publications were used to compile data on the surface sediments for the Quaternary sediments map. These publications were of many types, from county soil surveys of the early 20th century to modern, detailed geologic maps. To adapt these different types of maps to the uniform classification system of the Quaternary sediments map, extensive interpretation of all available data was required. Overall, the reliability of the map data is considered to be moderate for upstate New York and high for Long Island.

Thickness information.—Sediment thickness distribution is poorly known for upstate New York, whereas, for Long Island, the density of data allows a good estimate of thickness. For upstate New York, data from 31 publications were used to estimate thicknesses. In general, these data were well logs, and coverage for the State was overall quite low. For Long Island, topographic maps of the top of the underlying Coastal Plain surface contained in 14 publications were used to compile sediment thicknesses. For upstate New York, the reliability of the map data is considered to be low; for Long Island, it is moderately high.

Subsurface information.—In upstate New York, the nature of the subsurface deposits is not well known, and the Quaternary sediments map shows buried units in only a few areas. On Long Island, however, well control is good, and major buried units are shown diagrammatically.

Surficial and Stack-Unit Information

UPSTATE NEW YORK

Austin, M.E., Carlisle, F.J., McCracken, R.J., Dushek, L., and others, 1958, Soil survey of Franklin County, New York: Washington, D.C., U.S. Soil Conservation Service, 75 p., scale 1:20,000.

Austin, M.E., Lounsbury, C., Pearson, C.S., Benson, W.E., and others, 1953, Soil survey of Tioga County, New York: Washington, D.C., U.S. Soil Conservation Service, 133 p., scale 1:31,680.

Brigham, A.P., 1929, Glacial geology and geographic conditions of the lower Mohawk Valley: New York State Museum Bulletin 280, 133 p., scale 1:62,500.

Carlisle, F.J., Austin, M.E., McCracken, R.J., Dushek, L., and others, 1958, Soil survey of Franklin County, New York: Washington, D.C., U.S. Soil Conservation Service, 75 p., scale approx. 1:125,000.

Carr, M.E., Gilbert, B.D., Morrison, T.M., and Maxon, E.T., 1911, Soil survey of Jefferson County, New York: Washington, D.C., U.S. Soil Conservation Service, 83 p., scale 1:62,500.

Carr, M.E., Lee, O., Jr., Maynadier, G.B., Hallock, D.J., and Frost, V.J., 1910, Soil survey of Ontario County, New York: Washington, D.C., U.S. Soil Conservation Service, 55 p., scale 1:62,500.

Connally, G.G., 1973, Surficial geology of the Glens Falls region, New York: New York State Museum and Science Service Map and Chart Series no. 23, scale 1:48,000.

Crabb, G.A., and Morrison, T.M., 1912, Soil survey of Orange County, New York: Washington, D.C., U.S. Soil Conservation Service, 56 p., scale 1:62,500.

Davis, L.B., Landry, R.J., Krawiecki, V.J., Work, R., and others, 1978, Soil survey of Montgomery and Schenectady Counties, New York: Washington, D.C., U.S. Soil Conservation Service, 167 p., scale 1:62,500.

Denny, C.S., 1974, Pleistocene geology of the northeast Adirondack region, New York: U.S. Geological Survey Professional Paper 786, 50 p., scale 1:250,000.

Denny, C.S., and Lyford, W.H., 1963, Surficial geology and soils of the Elmira-Williamsport region, New York and Pennsylvania: U.S. Geological Survey Professional Paper 379, 60 p., scale 1:250,000.

Dineen, R.J., and Hanson, E.L., 1983, Bedrock topography and glacial deposits of the Colonie Channel between Saratoga Lake and Coeymans, New York: New York State Museum and Science Service Map and Chart Series no. 37, 24 p., scale 1:48,000.

Feuer, R., Garman, W.L., and Cline, M., 1955, Soils of Essex County, New York, 1955: Cornell University, Cooperative Extension Service, Soil Association Leaflet no. 4, 6 p., scale approx. 1:150,000.

Flach, K., Gile, L., and Feuer, R., 1957, Greene County soils: Cornell University, Cooperative Extension Service, Soil Association Leaflet no. 7, 6 p., scale approx. 1:103,000.

Hanna, W.E., Giddings, E.B., Rice, C.E., Laux, B.R., and Witty, J.E., 1981, Soil survey of Madison County, New York: Washington, D.C., U.S. Soil Conservation Service, 238 p., scale 1:62,500.

Howe, F.B., Buckman, H.O., and Lewis, H.G., 1920, Soil survey of Tompkins County, New York: Washington, D.C., U.S. Soil Conservation Service, 56 p., scale 1:62,500.

Hutton, F.Z., Jr., and Rice, C.E., 1977, Soil survey of Onondaga County, New York: Washington, D.C., U.S. Soil Conservation Service, 235 p., scale 1:62,500.

Kantrowitz, I.H., and Snavely, D.S., 1982, Availability of water from aquifers in upstate New York: U.S. Geological Survey Open-File Report 82–437, scale 1:750,000.

Knox, E.G., Garman, W.L., and Cline, M.G., 1954, Orange County soils: Cornell University, Cooperative Extension Service, Soil Association Leaflet no. 2, 6 p., scale approx. 1:110,000.

La Fleur, R.G., 1965, Glacial geology of the Troy, N.Y., quadrangle: New York State Museum and Science Service Map and Chart Series no. 7, 22 p., scale 1:31,680.

Latimer, W.J., Diebold, C.H., Secor, W., Mead, C.P., and Howard, M., Jr., 1937, Soil survey of Rensselaer County, New York: Washington, D.C., U.S. Soil Conservation Service, 70 p., scale 1:62,500.

Latimer, W.J., Howard, M., Jr., Gibbs, G., Huff, W., and Pearson, C.S., 1938, Soil survey of Onondaga County, New York: Washington, D.C., U.S. Soil Conservation Service, 78 p., scale 1:62,500.

Lewis, H.G., Brookins, E.F., Gillett, R.L., Howe, F.B., and Kinsman, D.F., 1922, Soil survey of Cayuga County, New York: Washington, D.C., U.S. Soil Conservation Service, 60 p., scale 1:62,500.

Lewis, H.G., Brookins, E.F., Howe, F.B., and Kinsman, D.F., 1923, Soil survey of Herkimer County area, New York: Washington, D.C., U.S. Soil Conservation Service, 48 p., scale 1:62,500.

Lewis, H.G., and Kinsman, D.F., 1923, Soil survey of Columbia County, New York: Washington, D.C., U.S. Soil Conservation Service, 43 p., scale 1:62,500.

Lounsbury, C., Beers, P.D., Howe, F.B., Waite, E.E., Pearson, C.S., and Diebold, C.H., 1930, Soil survey of Delaware County, New York: Washington, D.C., U.S. Soil Conservation Service, 31 p., scale 1:62,500.

Lounsbury, C., Hasty, A.H., Kinsman, D.F., and Baran, J.H., 1932, Soil survey of Broome County, New York: Washington, D.C., U.S. Soil Conservation Service, 40 p., scale 1:62,500.

Lounsbury, C., Lewis, H.G., Howe, F.B., and Diadato, S., 1925, Soil survey of St. Lawrence County, New York: Washington, D.C., U.S. Soil Conservation Service, 44 p., scale 1:62,500.

Lounsbury, C., Wildermuth, R., Benson, W.E., and Kinsman, D.F., 1942, Soil survey of Albany and Schenectady Counties, New York: Washington, D.C., U.S. Soil Conservation Service, 79 p., scale 1:62,500.

MacClintock, P., and Stewart, D.P., 1965, Pleistocene geology of the St. Lawrence Lowland: New York State Museum and Science Service Bulletin 394, 152 p., scale 1:125,000.

Maine, C.H., 1968, General soils report, Warren County: Washington, D.C., U.S. Soil Conservation Service and Warren County Soil and Water Conservation District, 24 p., scale approx. 1:155,000.

Maxon, E.T., 1916, Soil survey of Yates County, New York: Washington, D.C., U.S. Soil Conservation Service, 36 p., scale 1:62,500.

Maxon, E.T., and Bromley, J.H., 1917, Soil survey of Saratoga County, New York: Washington, D.C., U.S. Soil Conservation Service, 42 p., scale 1:62,500.

Maxon, E.T., Carr, M.E., and Stevens, E.H., 1913, Soil survey of Oneida County, New York: Washington, D.C., U.S. Soil Conservation Service, 59 p., scale 1:62,500.

Maxon, E.T., and Cone, W.R., 1914, Soil survey of Clinton County, New York: Washington, D.C., U.S. Soil Conservation Service, 37 p., scale 1:62,500.

Maxon, E.T., and Fuller, G.L., 1915, Soil survey of Schoharie County, New York: Washington, D.C., U.S. Soil Conservation Service, 34 p., scale 1:62,500.

———1916, Soil survey of Cortland County, New York: Washington, D.C., U.S. Soil Conservation Service, 28 p., scale 1:62,500.

Maxon, E.T., and Seltzer, W., 1918, Soil survey of Chenango County, New York: Washington, D.C., U.S. Soil Conservation Service, 37 p., scale 1:62,500.

Merrill, F.J.H., Darton, N.H., Hollick, Arthur, Salisbury, R.D., and others, 1902, Description of the New York City district: [New York-New Jersey] U.S. Geological Survey Geologic Atlas, Folio 83, scale 1:62,500.

Muller, E.H., 1977, Quaternary geology of New York, Niagara sheet: New York State Museum and Science Service Map 28, scale 1:250,000.

———1984, advance draft of mapping in central New York State: Syracuse University, scale 1:250,000.

Oswego County Planning Board, 1981, Glacial geology of Oswego County, New York: New York State Office of Planning Services, scale 1:63,360; compiled from 1:24,000-scale USGS Open-File maps, 1979–1980, by T.S. Miller, E.H. Muller, and others.

Parker, G.G., Hely, A.G., Keighton, W.B., Olmsted, F.H., and others, 1964, Water resources of the Delaware River basin: U.S. Geological Survey Professional Paper 381, 200 p., scale 1:500,000.

Pearson, C.S., Child, R.B., Kennedy, W.E., Huff, W., and Lawrence, C.B., 1942, Soil survey of Seneca County, New York: Washington, D.C., U.S. Soil Conservation Service, 68 p., scale 1:62,500.

Pearson, C.S., Cline, M.G., Sherrell, A., Grossman, R., and others, 1960, Soil survey of Lewis County, New York: Washington, D.C., U.S. Soil Conservation Service, 107 p., scale 1:125,000.

Pearson, C.S., Cline, M.G., Tedrow, N.P., Lounsbury, C., and others, 1956, Soil survey of Allegany County, New York: Washington, D.C., U.S. Soil Conservation Service, 141 p., scale 1:31,680.

Pearson, C.S., Howe, F.B., Kinsman, D.F., Wildermuth, R., Roberts, R.C., and Hasty, A.H., 1931, Soil survey of Steuben County, New York: Washington, D.C., U.S. Soil Conservation Service, 62 p., scale 1:62,500.

Pearson, C.S., Johnsgard, G.A., Secor, W., Kerr, H.A., and others, 1956, Soil survey of Livingston County, New York: Washington, D.C., U.S. Soil Conservation Service, 120 p., scale 1:31,680.

Pearson, C.S., Reitz, W.W., Mack, J., Ellsworth, W., and Schwartz, J., 1932, Soil survey of Chemung County, New York: Washington, D.C., U.S. Soil Conservation Service, 42 p., scale 1:62,500.

Puglia, P.S., Bauter, P.R., Broad, W.A., Parsons, R.A., Wulforst, J.P., and Pearson, C.S., 1979, Soil survey of Schuyler County, New York: Washington, D.C., U.S. Soil Conservation Service, 192 p., scale 1:190,080 and 1:15,840.

Rich, J.L., 1935, Glacial geology of the Catskills: New York State Museum Bulletin 299, 180 p., scale 1:125,000.

Secor, W., Kinsman, D.F., Benson, W.E., Lawrence, C.B., DeGolyer, W., and Lounsbury, C., 1946, Soil survey of Sullivan County, New York: Washington, D.C., U.S. Soil Conservation Service, 99 p., scale 1:62,500.

Secor, W., Koehler, L.F., Kinsman, D.F., Benson, W.E., and others, 1955, Soil survey of Dutchess County, New York: Washington, D.C., U.S. Soil Conservation Service, 178 p., scales 1:400,000 and 1:31,680.

Sweet, A.T., and Secor, W., 1940, Soil survey of Ulster County, New York: Washington, D.C., U.S. Soil Conservation Service, 52 p., scale 1:62,500.

Tharp, W.E., Lounsbury, C., Reitz, W.W., Diebold, C.H., Bauer, A.J., and Kinsman, D.F., 1940, Soil survey of Otsego County, New York: Washington, D.C., U.S. Soil Conservation Service, 64 p., scale 1:62,500.

Van Duyne, C., and Bromley, J.H., 1919, Soil survey of the White Plains area, New York: Washington, D.C., U.S. Soil Conservation Service, 44 p., scale 1:62,500.

Van Duyne, C., Kirk, N.M., Seltzer, W., Gum, J.P., and Erde, H.W., 1919, Soil survey of Wayne County, New York: Washington, D.C., U.S. Soil Conservation Service, 76 p., scale 1:62,500.

Waller, R.M., 1976, Surficial geologic map of the Black River basin, New York: U.S. Geological Survey Miscellaneous Field Studies Map MF–728–A, scale 1:125,000.

Winkley, H.E., Laux, B.R., Maine, C.H., Olsson, K.S., Phillips, J.A., and Scanu, R.J., 1975, Soil survey of Washington County, New York: Washington, D.C., U.S. Soil Conservation Service, 149 p., scale 1:63,360.

Woodrow, D.L., Blackburn, T.R., and Monahan, E.C., 1969, Geological, chemical, and physical attributes of sediments in Seneca Lake, New York, in Proceedings, 12th Conference on Great Lakes Research: Ann Arbor, Mich., International Association for Great Lakes Research, p. 380–396.

LONG ISLAND

De Laguna, Wallace, 1963, Geology of Brookhaven National Laboratory and vicinity, Suffolk County, New York: U.S. Geological Survey Bulletin 1156–A, 35 p.

Doriski, T.P., and Wilde-Katz, Franceska, 1983, Geology of the "20-foot" clay and Gardiners Clay in southern Nassau and southwestern Suffolk Counties, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 82–4056, 17 p., Scale approx. 1:95,000.
Fuller, M.L., 1914, The geology of Long Island, New York: U.S. Geological Survey Professional Paper 82, 231 p., scale 1:125,000.
Kilburn, Chabot, 1979, Hydrogeology of the Town of North Hempstead, Nassau County, Long Island, New York: Long Island Water Resources Bulletin 12, 87 p., scale approx. 1:107,000.
Kilburn, Chabot, and Krulikas, R.K., 1987, Hydrogeology and ground-water quality of the northern part of the Town of Oyster Bay, Nassau County, New York, in 1980: U.S. Geological Survey Water-Resources Investigations Report 85–4051, 61 p.
Krulikas, R.K., and Koszalka, E.J., 1983, Geologic reconnaissance of an extensive clay unit in north-central Suffolk County, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 82–4075, 9 p., scale approx. 1:280,000.
Lubke, E.R., 1964, Hydrogeology of the Huntington-Smithtown area, Suffolk County, New York: U.S. Geological Survey Water-Supply Paper 1669–D, 68 p.
Nemickas, Bronius, and Koszalka, E.J., 1982, Geohydrologic appraisal of water resources of the South Fork, Long Island, New York: U.S. Geological Survey Water-Supply Paper 2073, 55 p., scale 1:125,000.
Smolensky, D.A., Buxton, H.T., and Shernoff, P.K., in press, Hydrogeologic framework of Long Island, New York: U.S. Geological Survey Hydrologic Investigations Atlas HA–709, scale 1:125,000.
Soren, Julian, 1971, Ground-water and geohydrologic conditions in Queens County, Long Island, New York: U.S. Geological Survey Water-Supply Paper 2001–A, 39 p.
———1978, Hydrogeologic conditions in the Town of Shelter Island, Suffolk County, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 77–77, 22 p.
Soren, Julian, and Stelz, W.G., 1984, Aldicarb pesticide contamination of ground water in eastern Suffolk County, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 84–4251, 34 p.

Thickness Information

UPSTATE NEW YORK

Arnow, T., 1949, The ground-water resources of Albany County, New York: New York Water Power and Control Commission Bulletin GW–20, 56 p.
———1951, The ground-water resources of Columbia County, New York: New York Water Power and Control Commission Bulletin GW–25, 48 p., scale approx. 1:130,000.
———1951, The ground-water resources of Fulton County, New York: New York Water Power and Control Commission Bulletin GW–24, 48 p.
Asselstine, E.S., 1946, Progress report on ground-water conditions in the Cortland quadrangle, New York: New York Water Power and Control Commission Bulletin GW–16, 49 p.
Berdan, J.M., 1950, The ground-water resources of Schoharie County, New York: New York Water Power and Control Commission Bulletin GW–22, 61 p.
Berkey, C.P., and Rice, M., 1919, Geology of the West Point quadrangle: New York State Museum Bulletin 225 and 226, 152 p.

Calkin, P.E., Hodge, D.S., Champion, D.E., Oaksford, E.T., and Palmer, E.C., 1974, Gravity delineation of the preglacial Cazenovia River valley, western New York State, U.S.A.: Zeitschrift f_r Geomorphologie Neue Folge [Annals of Geomorphology], v. 18, no. 3, p. 247–259.

Crain, L.J., 1974, Ground-water resources of the western Oswego River basin, New York: New York Department of Environmental Conservation Basin Planning Report ORB–5, 137 p.

Cushman, R.V., 1950, The ground-water resources of Rensselaer County, New York: New York Water Power and Control Commission Bulletin GW–21, 56 p.

Daniels, R.B., and Owens, D.W., 1975, Glacial lake sediments in West Branch Cazenovia and Eighteenmile Creek valleys near Colden, New York: Washington, D.C., U.S. Soil Conservation Service, unpublished report, 11 p.

Denny, C.S., and Lyford, W.H., 1963, Surficial geology and soils of the Elmira-Williamsport region, New York and Pennsylvania: U.S. Geological Survey Professional Paper 379, 60 p.

Dineen, R.J., and Hanson, E.L., 1983, Bedrock topography and glacial deposits of the Colonie Channel between Saratoga Lake and Coeymans, New York: New York State Museum and Science Service Map and Chart Series no. 37, 24 p., scale 1:48,000.

Flint, J.J., and Lolcama, J., 1985, Buried ancestral drainage between Lakes Erie and Ontario: Geological Society of America Bulletin 97, p. 75–84.

Fluhr, T.W., 1962, New York bay—Bedrock profile: Geological Society of America Bulletin 73, p. 261–262.

Frimpter, M.H.,1972, Ground-water resources of Orange and Ulster Counties, New York: U.S. Geological Survey Water-Supply Paper 1985, 80 p., scale 1:125,000.

———1974, Ground-water resources, Allegheny River basin and part of the Lake Erie basin, New York: New York Department of Environmental Conservation Basin Planning Report ARB–2, 98 p.

Gilbert, B.K., and Kammerer, J.C., 1969, Analysis and interpretation of water resources data of the Genessee River basin, New York and Pennsylvania: U.S. Geological Survey Open-File Report, 363 p.

Grossman, I.G., and Yarger, L.B., 1953, Water resources of the Rochester area, New York: U.S. Geological Survey Circular 246, 30 p., scale 1:140,000.

Kantrowitz, I.H., 1970, Ground-water resources in the eastern Oswego River basin, New York: New York Department of Environmental Conservation Basin Planning Report ORB–2, 129 p.

LaSala, A.M., Jr., 1968, Ground-water resources of the Erie-Niagara basin, New York: New York Department of Environmental Conservation Basin Planning Report ENB–3, 114 p.

MacClintock, P., and Apfel, E.T., 1944, Correlation of the drifts of the Salamanca re-entrant, New York: Geological Society of America Bulletin, v. 55, p. 1143–1164.

MacNish, R.D., and Randall, A.D., 1982, Stratified-drift aquifers in the Susquehanna River basin, New York: New York Department of Environmental Conservation Bulletin 75, 68 p.

Mozola, A.J., 1951, The ground-water resources of Seneca County, New York: New York Water Power and Control Commission Bulletin GW–26, 57 p., scale approx. 1:128,000.

Newman, W.S., Thurber, D.H., Zeiss, H.S., Rokach, A., and Musich, L., 1969, Late Quaternary geology of the Hudson River estuary: a preliminary report: New York Academy of Science Transactions, v. 31, no. 5, p. 548–570.

Perlmutter, N.M., 1959, Geology and ground-water resources of Rockland County, New York: New York Water Power and Control Commission Bulletin GW–42, 133 p.

Perlmutter, N.M., and Arnow, T., 1953, Ground water in Bronx, New York, and Richmond Counties with summary data on Kings and Queens Counties, New York City, New York: New York Water Power and Control Commission Bulletin GW–32, 86 p., scale approx. 1:97,000.

Simpson, E.S., 1949, Buried preglacial groundwater channels in the Albany-Schenectady area in New York: Economic Geology, v. 44, no. 8, p. 713–720, scale approx. 1:200,000.

Waller, R.M., and Ayer, G.R., 1975, Water resources of the Black River basin, New York: New York Department of Environmental Conservation Basin Planning Report BRB–1, 205 p.

Waller, R.M., and Finch, A.J., 1982, Atlas of eleven selected aquifers in New York: U.S. Geological Survey Water-Resources Investigations Report 82–553, 255 p.

Woodrow, D.L., Blackburn, T.R., and Monahan, E.C., 1969, Geological, chemical, and physical attributes of sediments in Seneca Lake, New York, in Proceedings, 12th Conference on Great Lakes Research: Ann Arbor, Mich., International Association for Great Lakes Research, p. 380–396.

Worzel, J.L., and Drake, C.L., 1959, Structure section across the Hudson River at Nyack, New York, from seismic observations: New York Academy of Science Annals, v. 80, art. 4, p. 1092–1105.

LONG ISLAND, STATEN ISLAND, AND ADJACENT WATERS

Buxton, H.T., Soren, J., Posner, A., and Shernoff, P.K., 1981, Reconnaissance of the ground-water resources of Kings and Queens Counties, New York: U.S. Geological Survey Open-File Report 81–1186, 59 p., scale approx. 1:210,000.

Doriski, T.P., and Wilde-Katz, Franceska, 1983, Geology of the "20-foot" clay and Gardiners clay in southern Nassau and southwestern Suffolk Counties, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 82–4056, 17 p., scale approx. 1:95,000.

Isbister, J., 1966, Geology and hydrology of northeastern Nassau County, Long Island, New York: U.S. Geological Survey Water-Supply Paper 1825, 89 p., scale 1:48,000 and 1:170,000.

Jensen, H.M., and Soren, J., 1974, Hydrogeology of Suffolk County, Long Island, New York: U.S. Geological Survey Hydrologic Investigations Atlas HA–501, scale 1:250,000.

Kilburn, Chabot, 1979, Hydrogeology of the Town of North Hempstead, Nassau County, Long Island, New York: Long Island Water Resources Bulletin 12, 87 p., scale approx. 1:107,000.

Kilburn, Chabot, and Krulikas, R.K., 1987, Hydrogeology and groundwater quality of the northern part of the Town of Oyster Bay, Nassau County, Long Island, in 1980: U.S. Geological Survey Water-Resources Investigations Report 85–4051, 61 p.

Krulikas, R.K., and Koszalka, E.J., 1983, Geologic reconnaissance of an extensive clay unit in north-central Suffolk County, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 82–4075, 9 p., scale approx. 1:280,000.

Krulikas, R.K., Koszalka, E.J., and Doriski, T.P., 1983, Altitude of the top of the Matawan Group-Magothy Formation, Suffolk County, Long Island, New York: U.S. Geological Survey Open-File Report 83–137, scale 1:125,000.

Lewis, R.S., and Needell, S.W., 1987, Maps showing the stratigraphic framework and Quaternary geologic history of eastern Long Island Sound: U.S. Geological Survey Miscellaneous Field Studies Map MF–1939–A, 7 p., 3 sheets, scale 1:125,000.

Lovegreen, J.R., 1974, Paleodrainage of the Hudson estuary: New York, Columbia University, M.S. thesis, 151 p., scale 1:24,000.

Needell, S.W., and Lewis, R.S., 1984, Geology and structure of Block Island Sound, Rhode Island and New York: U.S. Geological Survey Miscellaneous Field Studies Map MF–1621, 4 sheets, scale 1:125,000.
Perlmutter, N.M., and Geraghty, J.J., 1963, Geology and ground-water conditions in southern Nassau and southeastern Queens Counties, Long Island, New York: U.S. Geological Survey Water-Supply Paper 1613–A, 205 p., scale 1:200,000.
Smolensky, D.A., Buxton, H.T., and Shernoff, P.K., in press, Hydrogeologic framework of Long Island, New York: U.S. Geological Survey Hydrologic Investigations Atlas HA–709, scale 1:125,000.
Swarzenski, W.V., 1963, Hydrogeology of northwestern Nassau and northeastern Queens Counties, Long Island, New York: U.S. Geological Survey Water-Supply Paper 1657, 90 p., scale 1:48,000.

Additional References

Chapman, D.H., 1937, Late-glacial and postglacial history of the Champlain valley: American Journal of Science, 5th ser., v. 34, no. 200, p. 89–124. (Limit of late Wisconsinan marine invasion)
Fairchild, H.L., 1907, Drumlins of central western New York: New York State Museum Bulletin 111, p. 391–443. (Drumlins) (Elsewhere in the State, particularly southeast of the Catskills and east of the Hudson River, drumlins are known to be numerous in places but are unmapped.)
Fisher, D.W., Isachsen, Y.W., and Rickard, L.V., 1970, Geologic map of New York, Hudson-Mohawk sheet: New York State Museum and Science Service Map and Chart Series no. 15, scale 1:250,000. (Till texture)
———1970, Geologic map of New York, Lower Mohawk sheet: New York State Museum and Science Service Map and Chart Series no. 15, scale 1:250,000. (Till texture)
Isachsen, Y.W., and Fisher, D.W., 1970, Geologic map of New York, Adirondack sheet: New York State Museum and Science Service Map and Chart Series no. 15, scale 1:250,000. (Till texture)
Rickard, L.V., and Fisher, D.W., 1970, Geologic map of New York, Finger Lakes sheet: New York State Museum and Science Service Map and Chart Series no. 15, scale 1:250,000. (Till texture)
———1970, Geologic map of New York, Niagara sheet: New York State Museum and Science Service Map and Chart Series no. 15, scale 1:250,000. (Till texture)

NORTH DAKOTA

Overview of Quaternary deposits.—Surface sediments in North Dakota are dominantly till. In the western half of the State, the till is sandy; to the east, the till is more clayey. Large areas of stratified deposits are associated with the end moraine in south-central North Dakota, where coarse-grained sediments dominate, and in glacial lake basins, where both coarse- and fine-grained sediments are found. Along the eastern border of the State, fine-grained stratified sediment dominates in the glacial Lake Agassiz basin. In the north-central region, both coarse- and fine-grained sediments occur in the glacial Lake Souris basin. Sediment thickness is commonly greater than 50 ft, except along a large north-south ridge in east-central North Dakota and near the glacial margin. An extensive network of buried valleys occurs in central North Dakota, where sediment thicknesses may exceed 400 ft in places. In the Lake Agassiz basin, between 200 and 400 ft of sediment is common.

Surficial information.—Statewide surficial geologic maps were available (Bluemle, 1977; Clayton, 1980) at scales of 1:1,000,000 and 1:500,000, respectively. These maps were used to compile the Quaternary sediments map and were supplemented with more than 10 detailed maps of specific areas to improve the interpretations, since not all geologic units on the statewide maps could be properly interpreted by the classification scheme of the Quaternary sediments map. Overall, the reliability of the map data is considered to be moderately high.

Thickness information.—A preliminary statewide map of sediment thickness (Bluemle, 1971), scale 1:500,000, served as the basis for compilation of thickness data for the Quaternary sediments map. Because the statewide map was generalized and eight more recent maps of smaller areas were available, extensive reinterpretation of the map was required. The reliability of the map data is considered to be moderate.

Subsurface information.—Some county geologic reports contain generalized subsurface data in cross sections. These data were used to show diagrammatically the probable extent of certain major buried units such as extensive aquifers.

Surficial and Stack-Unit Information

Armstrong, C.A., 1982, Ground-water resources of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69, pt. 3, 51 p.

Arndt, B.M., 1975, Geology of Cavalier and Pembina Counties: North Dakota Geological Survey Bulletin 62, pt. 1, 68 p., scale 1:250,000.

Baker, C.H., Jr., 1967, Geology and ground water resources of Richland County: North Dakota Geological Survey Bulletin 46, pt. 1, 45 p., scale 1:125,000.

Bluemle, J.P., 1967, Geology and ground water resources of Traill County: North Dakota Geological Survey Bulletin 49, pt. 1, 34 p., scale 1:125,000.

———1973, Geology of Nelson and Walsh Counties, North Dakota: North Dakota Geological Survey Bulletin 57, pt. 1, 70 p., scale 1:125,000.

———1975, Geology of Griggs and Steele Counties: North Dakota Geological Survey Bulletin 64, pt. 1, 50 p.

*———1977, Geologic highway map of North Dakota: North Dakota Geological Survey Miscellaneous Map 19, scale 1:1,000,000.

———1979, Geology of Dickey and LaMoure Counties: North Dakota Geological Survey Bulletin 70, pt. 1, 72 p.

———1979, Geology of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69, pt. 1, 84 p., scale 1:125,000.

*Clayton, Lee, 1980, Geologic map of North Dakota: Reston, Va., U.S. Geological Survey, scale 1:500,000.

Clayton, Lee, Moran, S.R., and Bluemle, J.P., 1980, Explanatory text to accompany the geologic map of North Dakota: North Dakota Geological Survey Report of Investigation 69, 93 p.

Colton, R.B., Lemke, R.W., and Lindvall, R.M., 1963, Preliminary glacial map of North Dakota: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–331, scale 1:500,000.

Hansen, D.E., and Kume, Jack, 1970, Geology and ground water resources of Grand Forks County: North Dakota Geological Survey Bulletin 53, pt. 1, 76 p., scale 1:125,000.

Klausing, R.L., 1968, Geology and ground water resources of Cass County, North Dakota: North Dakota Geological Survey Bulletin 47, pt. 1, 39 p., scale 1:125,000.

Larsen, W.M., Omodt, Hollis, Evanson, Eldon, Kerl, Donald, and Dunnigan, Lorn, 1964, Soil survey of Sargent County, North Dakota: Washington, D.C., U.S. Soil Conservation Service, 97 p., scale 1:190,080.

Leverett, Frank, 1932, Quaternary geology of Minnesota and parts of adjacent states: U.S. Geological Survey Professional Paper 161, 149 p., scale 1:62,500.

Thickness Information

Arndt, B.M., 1975, Geology of Cavalier and Pembina Counties: North Dakota Geological Survey Bulletin 62, pt. 1, 68 p., scale 1:250,000.

*Bluemle, J.P., 1971, Depth to bedrock in North Dakota, a preliminary map: North Dakota Geological Survey Miscellaneous Map 13, scale 1:500,000.

———1979, Geology of Dickey and LaMoure Counties: North Dakota Geological Survey Bulletin 70, pt. 1, 72 p., scale approx. 1:700,000.

———1979, Geology of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69, pt. 1, 84 p., scale 1:500,000.

———1981, Geology of Sheridan County, North Dakota: North Dakota Geological Survey Bulletin 75, pt. 1, 59 p., scale 1:500,000.

———1982, Geology of McHenry County, North Dakota: North Dakota Geological Survey Bulletin 74, pt. 1, 49 p., scale 1:250,000.

———1984, Geology of Emmons County, North Dakota: North Dakota Geological Survey Bulletin 66, pt. 1, 69 p., scale 1:250,000.

———1984, Geology of Towner County, North Dakota: North Dakota Geological Survey Bulletin 79, pt. 1, 44 p., scale 1:500,000.

Carlson, C.G., and Freers, T.F., 1975, Geology of Benson and Pierce Counties, North Dakota: North Dakota Geological Survey Bulletin 59, pt. 1, 32 p., scale 1:125,000.

Additional Reference

Bluemle, J.P., 1982, Bedrock geologic map of North Dakota: North Dakota Geological Survey Miscellaneous Map 21, scale 1:1,000,000. (Till texture)

OHIO

Overview of Quaternary deposits.—Surface sediments are dominantly clayey till in the lowlands south and west of Lake Erie in northern Ohio, whereas till is silty to the south of the lake lowlands. Large areas of stratified deposits, generally coarse grained, are confined to the valleys of large rivers such as the Great Miami and Scioto. Fine-grained stratified deposits in places overlie till on the lake lowlands and in ice-gouged valleys in northeastern Ohio. Sediment thickness on uplands is generally less than 50 ft except over the extensive network of preglacial and interglacial buried valleys in central Ohio, where sediment thicknesses in places exceed 400 ft. In the stratified deposits in valleys, sediment is commonly more than 100 ft thick. In the ice-gouged valley beneath the lower Cuyahoga River, thicknesses exceed 600 ft.

Surficial information.—Although a statewide surficial map (Goldthwait and others, 1961), scale 1:500,000, served as the basic data source, several other maps and written communications were also used. The statewide map emphasized glacial ages and ice advances, whereas the Quaternary sediments map emphasizes sediment character; the difference between the two mapping schemes was so great that extensive reinterpretation and incorporation of other, more detailed mapping was necessary. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from maps of bedrock-surface topography, sediment thickness, and land-surface topography and from well data. Seventy-nine publications were used to compile an interim publication (Soller, 1986), which was then used to compile the Quaternary sediments map. The reliability of map data is considered to be moderately high.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Ohio. In places where detailed study has shown the presence of extensive and thick buried units, they were shown diagrammatically.

Surficial and Stack-Unit Information

Burger, A.M., Forsyth, J.L., Nicoll, R.S., and Wayne, W.J., 1971, Geologic map of the 1_x2_ Muncie quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 5, scale 1:250,000.

Goldthwait, R.P., 1985, Glacial map of Ohio: written communication (unpublished map), scale 1:250,000.

Goldthwait, R.P., White, G.W., and Forsyth, J.L., 1961, Glacial map of Ohio: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–316, scale 1:500,000.

Gray, H.H., Forsyth, J.L., Schneider, A.F., and Gooding, A.M., 1972, Geologic map of the 1_x2_ Cincinnati quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 7, scale 1:250,000.

Johnson, G.H., and Keller, S.J., 1972, Geologic map of the $1^{o}x2^{o}$ Fort Wayne quadrangle, Indiana, Michigan, and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 8, scale 1:250,000.

Lerch, N.K., Hale, W.F., and Lemaster, D.D., 1982, Soil survey of Hamilton County, Ohio: Washington, D.C., U.S. Soil Conservation Service, 219 p.

White, G.W., 1982, Glacial geology of northeastern Ohio: Ohio Geological Survey Bulletin 68, 75 p., scale 1:250,000.

Thickness Information

Soller, D.R., 1986, Preliminary map showing the thickness of glacial deposits in Ohio: U.S. Geological Survey Miscellaneous Field Studies Map MF–1862, scale 1:500,000. (Compiled from 79 publications.)

PENNSYLVANIA

Overview of Quaternary deposits.—Surface sediments are dominantly silty till in northwestern Pennsylvania and sandy till in northeastern Pennsylvania. In northeastern Pennsylvania, large areas of stratified deposits, mostly coarse grained, are confined to large river valleys. In northwestern Pennsylvania, fine-grained stratified deposits occur in deep, preglacial or interglacial buried valleys. Sediment thickness on the uplands is generally less than 50 ft, and, in much of northeastern Pennsylvania, the till cover is patchy and bedrock exposures are numerous, especially near the glacial margin. In the valleys of northeastern Pennsylvania, sediment thicknesses commonly are low, seldom exceeding 100 ft. In northwestern Pennsylvania, sediment thicknesses in the valleys are commonly 100 to 400 ft.

Surficial information.—Surficial mapping in northwestern Pennsylvania by Shepps and others (1959), scale 1:125,000, served as the basis for the Quaternary sediments map without extensive reinterpretation. In contrast, an adequate surficial map did not exist for northeastern Pennsylvania; nearly 50 publications ranging from detailed geologic maps to reconnaissance soil maps were used to compile the Quaternary sediments map. For northwestern Pennsylvania, the reliability of the map data is considered to be moderate, whereas data reliability for northeastern

Pennsylvania is considered to be moderately low.

Thickness information.—For northwestern Pennsylvania, sediment thickness was compiled from local sediment-thickness maps, bedrock-surface topographic maps, well data, and general geologic descriptions contained in 13 publications. For northeastern Pennsylvania, thickness data were sparse. The nearly 50 publications used for the surficial mapping, as well as additional sources including a computerized well inventory, were used to compile a generalized map of sediment thickness. The reliability of map data in northwestern Pennsylvania is considered to be moderately low, and, in northeastern Pennsylvania, it is considered to be low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Pennsylvania. In only one area, along the shore of Lake Erie, is the nature of the subsurface deposits shown.

Surficial and Stack-Unit Information

NORTHEASTERN PENNSYLVANIA

Alvord, D.C., and Drake, A.A., Jr., 1971, Geologic map of the Bushkill quadrangle, Pennsylvania-New Jersey: U.S. Geological Survey Geologic Quadrangle Map GQ–908, scale 1:24,000.

Bacon, S.R., Taylor, D., Boileau, A., and Yoder, G., 1946, Soil survey of Union County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 115 p., scale 1:48,000.

Berg, T.M., 1975, Geology and mineral resources of the Brodheadsville quadrangle, Monroe and Carbon Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 205a, 60 p., scale 1:24,000.

Berg, T.M., and Sevon, W.D., in press, Geology and mineral resources of Pike County: Pennsylvania Topographic and Geologic Survey Bulletin C52. (Advance draft of map, at scale 1:50,000, obtained for this compilation.)

Berg, T.M., Sevon, W.D., and Bucek, M.F., 1977, Geology and mineral resources of the Pocono Pines and Mount Pocono quadrangles, Monroe County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 204cd, 66 p., scale 1:24,000.

Bucek, M.F., 1971, Surficial geology of the East Stroudsburg 7.5-minute quadrangle, Monroe County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 214c, 40 p., scale 1:24,000.

Bush, R.D., Braker, W.L., Hallowich, J.S., Martin, G.W., and others, 1981, Soil survey of Luzerne County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 106 p., scale 1:253,440 and 1:20,000.

Carter, W.T., Jr., and Kerr, J.A., 1912, Soil survey of Lehigh County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 53 p., scale 1:62,500.

Crowl, G.H., 1971, Pleistocene geology and unconsolidated deposits of the Delaware valley, Matamoras to Shawnee on Delaware, Pennsylvania: Pennsylvania Topographic and Geologic Survey General Geological Report 60, 40 p., scale 1:24,000.

———1984, Pre-Woodfordian drifts of eastern Pennsylvania: written communication (unpublished map), scale 1:250,000.

Crowl, G.H., and Sevon, W.D., 1980, Glacial border deposits of Late Wisconsinan age in northeastern Pennsylvania: Pennsylvania Topographic and Geologic Survey General Geological Report 71, 68 p., scale 1:100,000.

Davis, R.E., Drake, A.A., Jr., and Epstein, J.B., 1967, Geologic map of the Bangor quadrangle, Pennsylvania-New Jersey: U.S. Geological Survey Geologic Quadrangle Map GQ–665, scale 1:24,000.

Denny, C.S., 1956, Surficial geology and geomorphology of Potter County, Pennsylvania: U.S.

Geological Survey Professional Paper 288, 72 p., scale 1:62,500.
Denny, C.S., and Lyford, W.H., 1963, Surficial geology and soils of the Elmira-Williamsport region, New York and Pennsylvania: U.S. Geological Survey Professional Paper 379, 60 p., scale 1:250,000.
Drake, A.A., Jr., 1967, Geologic map of the Easton quadrangle, New Jersey-Pennsylvania: U.S. Geological Survey Geologic Quadrangle Map GQ–594, scale 1:24,000.
Eckenrode, J.J., Holzer, D.B., Sautter, E.H., and Browning, S.A., 1982, Soil survey of Lackawanna and Wyoming Counties, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 166 p., scale 1:253,440.
Epstein, J.B., 1969, Surficial geology of the Stroudsburg quadrangle, Pennsylvania-New Jersey: Pennsylvania Topographic and Geologic Survey General Geological Report 57, 67 p., scale 1:24,000.
Epstein, J.B., Sevon, W.D., and Glaeser, J.D., 1974, Geology and mineral resources of the Lehighton and Palmerton quadrangles, Carbon and Northampton Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 195cd, 460 p., scale 1:24,000.
Faill, R.T., 1979, Geology and mineral resources of the Montoursville South and Muncy quadrangles and part of the Hughesville quadrangle, Lycoming, Northumberland, and Montour Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 144ab, 114 p., scale 1:24,000.
Faill, R.T., Wells, R.B., and Sevon, W.D., 1977, Geology and mineral resources of the Linden and Williamsport quadrangles, Lycoming County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 134ab, scale 1:24,000.
———1977, Geology and mineral resources of the Salladasburg and Cogan Station quadrangles, Lycoming County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 133cd, scale 1:24,000.
Fisher, G., Mattern, R., McCombs, R., Norgren, J., and Rebert, A., 1962, Soil survey of Carbon County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 108 p., scale 1:188,179 and 1:20,000.
Goodman, K.V., Tedrow, J.C.F., Stem, R.W., and Yearick, L.G., 1958, Soil survey of Potter County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 101 p., scale 1:20,000.
Hendrickson, B.H., Avon Burke, R.T., Goodman, K.V., and Smith, R.L., 1929, Soil survey of Tioga County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 47 p., scale 1:62,500.
———1929, Soil survey of Wyoming County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 36 p., scale 1:62,500.
Hollowell, J.R., 1971, Hydrology of the Pleistocene sediments in the Wyoming valley, Luzerne County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 28, 77 p., scale 1:24,000.
Inners, J.D., 1978, Geology and mineral resources of the Berwick quadrangle, Luzerne and Columbia Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 174c, 34 p., scale 1:24,000.
———1981, Geology and mineral resources of the Bloomsburg and Mifflinville quadrangles and part of the Catawissa quadrangle, Columbia County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 164cd, 152 p., scale 1:24,000.
Lockwood, W.N., and Meisler, Harold, 1960, Illinoian outwash in southeastern Pennsylvania: U.S. Geological Survey Bulletin 1121–B, 9 p.
Lohman, S.W., 1939, Ground water in north-central Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 6, 219 p., scale 1:380,160.

Miller, B.L., Fraser, D.M., Miller, R.L., Willard, B., and Wherry, E.T., 1941, Lehigh County, Pennsylvania, geology and geography: Pennsylvania Topographic and Geologic Survey Bulletin C39, 492 p., scale 1:62,500.

Owens, J.P., and Minard, J.P., 1975, Geologic map of the surficial deposits in the Trenton area, New Jersey and Pennsylvania: U.S. Geological Survey Miscellaneous Investigations Series Map I–884, scale 1:48,000.

Parker, G.G., Hely, A.G., Keighton, W.B., Olmsted, F.H., and others, 1964, Water resources of the Delaware River basin: U.S. Geological Survey Professional Paper 381, 200 p., scale 1:500,000.

Parrish, P.H., Tinsley, W.M., Zimmerman, R.P., Craver, R.K., Cruikshank, R., and Byrne, W.R., 1967, Soil survey of Columbia County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 139 p., scale 1:190,080 and 1:20,000.

Reber, E.J., Billings, P.G., and Pease, D.S., 1973, Soil survey of Susquehanna County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 89 p., scale 1:190,080 and 1:20,000.

Sevon, W.D., 1975, Geology and mineral resources of the Christmans and Pohopoco Mountain quadrangles, Carbon and Monroe Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 195ab, scale 1:24,000.

———1975, Geology and mineral resources of the Hickory Run and Blakeslee quadrangles, Carbon and Monroe Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 194cd, scale 1:24,000.

———1975, Geology and mineral resources of the Tobyhanna and Buck Hill Falls quadrangles, Monroe County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 204ab, scale 1:24,000.

Sevon, W.D., and Berg, T.M., 1978, Geology and mineral resources of the Skytop quadrangle, Monroe and Pike Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 214a, 33 p., scale 1:24,000.

Shaw, C.F., McKee, J.M., and Ross, W.G., 1911, A reconnaissance soil survey of northeastern Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 63 p., scale approx. 1:250,000.

———1912, A reconnaissance soil survey of southeastern Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 94 p., scale approx. 1:250,000.

Simmons, C.S., Atkinson, C.H., and Brown, L.A., 1938, Soil survey of Wayne County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 31 p., scale 1:62,500.

Staley, L.R., Tompkins, E.A., Bushong, T.J., and Huxson, H.J., 1974, Soil survey of Northampton County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 120 p., scale 1:190,080 and 1:15,840.

Stevens, E.H., Hendrickson, B.H., Manifold, C.B., Degen, C.G., and Patrick, A.L., 1923, Soil survey of Lycoming County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 51 p.

Taylor, D., Bacon, S.R., and Yearick, L.G., 1955, Soil survey of Montour and Northumberland Counties, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 152 p., scale 1:24,000.

Taylor, D.C., Billings, P., Fisher, G., and Trapp, G., 1969, Soil survey of Pike County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 83 p., scale approx. 1:250,000.

Wells, R.B., and Bucek, M.F., 1980, Geology and mineral resources of the Montoursville North and Huntersville quadrangles, Lycoming County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Atlas 143cd, 68 p., scale 1:24,000.

Willard, B., Freedman, J., McLaughlin, D.B., Ryan, J.D., and others, 1959, Geology and mineral resources of Bucks County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Bulletin C9, 243 p., scale 1:62,500.

Wood, P.O., McKee, J.M., Skemp, L.M., Nissley, W.B., and Dickey, J.B.R., 1911, Soil survey of Bradford County, Pennsylvania: Washington, D.C., U.S. Soil Conservation Service, 41 p., scale 1:63,360.

NORTHWESTERN PENNSYLVANIA

Carswell, L.D., and Bennett, G.D., 1963, Geology and hydrology of the Neshannock quadrangle, Mercer and Lawrence Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 15, 90 p., scale 1:24,000.

Legette, R.M., 1936, Ground water in northwestern Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 3, 215 p.

McCoy, H.J., 1985, U.S. Geological Survey, written communication of information later released as part of:

Richards, D.B., McCoy, H.J., and Gallaher, J.P., 1987, Groundwater resources of Erie County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 62, 101 p., scale 1:62,500.

Muller, E.H., 1977, Quaternary geology of New York, Niagara Sheet: New York State Museum and Science Service Map 28, scale 1:250,000.

Poth, C.W., 1963, Geology and hydrology of the Mercer quadrangle, Mercer, Lawrence, and Butler Counties, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 16, 149 p., scale 1:48,000.

———1973, Summary, Ground-water resources of Butler County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 36, 49 p., scale 1:125,000.

Preston, F.W., 1950, Introduction to Glacial Lake Arthur: Lake deposits and physiographic features, in Field Conference of Pennsylvania Geologists, 16th Annual Meeting, Pittsburgh, Pa., May 26–28: Harrisburg, Pa., Pennsylvania Topographic and Geologic Survey, p. 12–36.

Schiner, G.R., and Gallaher, J.T., 1979, Geology and groundwater resources of western Crawford County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 46, 103 p., scale 1:50,000.

Schiner, G.R., and Kimmel, G.E., 1976, Geology and ground-water resources of northern Mercer County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 33, 136 p., scale 1:24,000.

Schooler, E.E., 1974, Pleistocene beach ridges of northwestern Pennsylvania: Pennsylvania Topographic and Geologic Survey General Geological Report 64, 38 p., scale 1:62,500.

*Shepps, V.C., White, G.W., Droste, J.B., and Sitler, R.F., 1959, Glacial geology of northwestern Pennsylvania: Pennsylvania Topographic and Geologic Survey General Geological Report 32, 59 p., scale 1:125,000.

Van Tuyl, D.W., and Klein, N.H., 1951, Ground-water resources of Beaver County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 9, 84 p., scale 1:63,360.

White, G.W., Totten, S.M., and Gross, D.L., 1969, Pleistocene stratigraphy of northwestern Pennsylvania: Pennsylvania Topographic and Geologic Survey General Geological Report 55, 88 p.

Thickness Information

NORTHEASTERN PENNSYLVANIA

In addition to the following references, some of the references listed in the section on surficial and stack-unit information for northeastern Pennsylvania were used to map sediment thickness.

Carswell, L.D., and Lloyd, O.B., Jr., 1979, Geology and groundwater resources of Monroe County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 47, 61 p., scale 1:48,000.

Lloyd, O.B., Jr., and Carswell, L.D., 1981, Groundwater resources of the Williamsport region, Lycoming County, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 51, 69 p., scale 1:100,000.

Taylor, L.E., 1984, Groundwater resources of the upper Susquehanna River basin, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 58, 136 p., scale 1:250,000.

Taylor, L.E., Werkheiser, W.H., and Kriz, M.L., 1983, Groundwater resources of the West Branch Susquehanna River basin, Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 56, 143 p., scale 1:250,000.

U.S. Geological Survey, 1984, WATSTORE data base, computer file of well data.

Williams, J.H., and Eckhardt, D.A., 1987, Groundwater resources of the Berwick-Bloomsburg-Danville area, east-central Pennsylvania: Pennsylvania Topographic and Geologic Survey Water Resource Report 61, 76 p., scale 1:50,000.

NORTHWESTERN PENNSYLVANIA

See references for northwestern Pennsylvania under "Surficial and Stack-Unit Information."

Additional References

Berg, T.M., chief compiler, 1980, Geologic map of Pennsylvania: Harrisburg, Pa., Pennsylvania Topographic and Geologic Survey, scale 1:250,000. (Till texture)

White, G.W., 1982, Glacial geology of northeastern Ohio: Ohio Geological Survey Bulletin 68, 75 p., scale 1:250,000. (Till texture)

RHODE ISLAND

Overview of Quaternary deposits.—Surface sediments in Rhode Island are dominantly sandy till. Large areas of coarse-grained stratified sediment occur in valleys and adjacent to Narragansett Bay. Sediment thicknesses seldom exceed 50 ft, and, in many places, the till cover is patchy and bedrock exposures are numerous.

Surficial information.—A statewide compilation (Lang and others, 1960), scale 1:150,000, was used to compile the Quaternary sediments map; 13 detailed geologic maps were used to refine the mapping in certain areas. The reliability of the map data is considered to be moderately high.

Thickness information.—The thickness information for the Quaternary sediments map was compiled from nine publications. The reliability of the map data is considered to be moderately high.

Subsurface information.—Because of the small size of Rhode Island and the general lack of subsurface studies, buried units were not shown.

Surficial and Stack-Unit Information

Feininger, T.G., 1962, Surficial geology of the Hope Valley quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–166, scale 1:24,000.

Kaye, C.A., 1960, Surficial geology of the Kingston quadrangle, Rhode Island: U.S. Geological Survey Bulletin 1071–I, p. 341–396, scale 1:24,000.

*Lang, S.M., Bierschenk, W.H., and Allen, W.B., 1960, Hydraulic characteristics of glacial outwash in Rhode Island: Rhode Island Water Resources Coordinating Board Hydrologic Bulletin 3, 38 p., scale approx. 1:150,000.

Power, W.R., Jr., 1957, Surficial geology of the Slocum quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–106, scale 1:31,680.

Richmond, G.M., 1953, Surficial geology of the Georgiaville quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–22, scale 1:31,680.

Robinson, C.S., 1961, Surficial geology of the North Scituate quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–143, scale 1:24,000.

Schafer, J.P., 1961, Surficial geology of the Narragansett Pier quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–140, scale 1:24,000.

———1961, Surficial geology of the Wickford quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–136, scale 1:24,000.

———1965, Surficial geologic map of the Watch Hill quadrangle, Rhode Island-Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–410, scale 1:24,000.

Shute, N.E., 1949, Surficial geology of the Pawtucket quadrangle, Rhode Island-Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–2, scale 1:31,680.

Smith, H.J., 1955, Surficial geology of the Bristol quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–70, scale 1:31,680.

———1955, Surficial geology of the East Greenwich quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–62, scale 1:31,680.

———1956, Surficial geology of the Crompton quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–94, scale 1:31,680.

———1956, Surficial geology of the Providence quadrangle, Rhode Island: U.S. Geological Survey Geologic Quadrangle Map GQ–84, scale 1:31,680.

Thickness Information

Allen, W.B., 1953, The ground-water resources of Rhode Island—A reconnaissance: Rhode Island Water Resources Coordinating Board Geological Bulletin 6, scale approx. 1:125,000. (Till uplands)

Bierschenk, W.H., 1956, Ground-water resources of the Kingston quadrangle, Rhode Island: Rhode Island Development Council Geological Bulletin 9, 60 p., scale 1:31,680. (Charleston moraine, which is dominantly till)

Gonthier, J.B., Johnston, H.E., and Malmberg, G.T., 1974, Availability of ground water in the Lower Pawcatuck River basin, Rhode Island: U.S. Geological Survey Water-Supply Paper 2033, 40 p., scale 1:48,000. (Stratified drift)

Hahn, G.W., 1959, Ground-water map of the Narragansett Pier quadrangle, Rhode Island: Rhode Island Water Resources Coordinating Board Ground water map 5, scale 1:24,000. (Charleston moraine, which is dominantly till)

Johnson, K.E., 1961, Ground-water map of the Watch Hill quadrangle, Rhode Island-Connecticut: Rhode Island Water Resources Coordinating Board Ground Water Map 14, scale 1:24,000. (Charleston moraine, which is dominantly till)

Lang, S.M., 1961, Appraisal of the ground water reservoir areas in Rhode Island: Rhode Island Water Resources Coordinating Board Geological Bulletin 11, 38 p., scale approx. 1:38,000. (Stratified drift)
LaSala, A.M., Jr., and Hahn, G.W., 1960, Ground-water map of the Carolina quadrangle, Rhode Island: Rhode Island Water Resources Coordinating Board Ground Water Map 9, scale 1:24,000. (Charleston moraine, which is dominantly till)
LaSala, A.M., Jr., and Johnson, K.E., 1960, Ground-water map of the Quonochontaug quadrangle, Rhode Island: Rhode Island Water Resources Coordinating Board Ground Water Map 11, scale 1:24,000. (Charleston moraine, which is dominantly till)
Tuttle, C.R., Allen, W.B., and Hahn, G.W., 1961, A seismic record of Mesozoic rocks on Block Island, Rhode Island: U.S. Geological Survey Professional Paper 424–C, p. C254–C256.

SOUTH DAKOTA

Overview of Quaternary deposits.—Surface sediments in South Dakota are dominantly clayey till in the lowlands, whereas more silty till occurs near the margins of the glaciated area. Coarse-grained stratified deposits are distributed in patches on the uplands known as the Prairie Coteau in eastern South Dakota and in river valleys elsewhere. Fine-grained stratified deposits occur in the basin of glacial Lake Dakota, west of the Prairie Coteau. Sediment thicknesses vary greatly, from 400 to 800 ft beneath the Prairie Coteau to less than 50 ft in the Lake Dakota lowlands to the west. South and west of the lake basin, sediment thicknesses are commonly 100 ft or more, and they exceed 400 ft over some buried valleys. Along the glacial limit adjacent to the Missouri River, the sediment cover is patchy, and weathered rock commonly is exposed.

Surficial information.—A statewide surficial map (Bretz, 1984), scale 1:500,000, was used to compile the Quaternary sediments map and was supplemented by nine other publications and written communications in order to refine the map data and adapt the map units to the classification system. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from nine references containing bedrock-surface topographic and sediment-thickness maps and well data. The reliability of the map data is considered to be moderate.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in South Dakota, and only a limited amount of subsurface information, based on extrapolation of data from North Dakota, was shown.

Surficial and Stack-Unit Information

Baker, C.L., and Carlson, C.A., Jr., 1952, Areal geology of the Akaska quadrangle: Vermillion, S.D., South Dakota Geological Survey quadrangle map, scale 1:62,500.
*Bretz, R.F., 1984, Quaternary map of eastern South Dakota: Vermillion, S.D., South Dakota Geological Survey unpublished map, scale 1:500,000.
Flint, R.F., 1955, Pleistocene geology of eastern South Dakota: U.S. Geological Survey Professional Paper 262, 173 p., scale 1:500,000.
Hedges, L.S., 1972, Geology and water resources of Campbell County, South Dakota: South Dakota Geological Survey Bulletin 20, pt. 1, 39 p., scale 1:125,000.
———1975, Geology and water resources of Charles Mix and Douglas Counties, South Dakota: South Dakota Geological Survey Bulletin 22, pt. 1, 43 p., scale 1:125,000.
Hutton, J.G., 1935, Reconnaissance soil map of South Dakota: Vermillion, S.D., South Dakota Agricultural Experiment Station, scale 1:500,000.
Jarrett, M.J., 1986, Sand and gravel resources in Turner, Hutchinson, and Grant Counties, South

Dakota: South Dakota Geological Survey unpublished data in preparation for Information Pamphlets.
Leverett, Frank, 1932, Quaternary geology of Minnesota and parts of adjacent States: U.S. Geological Survey Professional Paper 161, 149 p., scale 1:62,500.
Schultz, L.D., Ensz, E.H., Kost, M.M., Miller, K.F., and Paschke, L.D., 1975, Soil survey of Marshall County, South Dakota: Washington, D.C., U.S. Soil Conservation Service, 116 p., scale 1:190,080.
Watkins, W.I., and Larson, G.A., 1925, Soil survey of Brown County, South Dakota: Washington, D.C., U.S. Soil Conservation Service, 32 p., scale 1:63,360.

Thickness Information

Christensen, C.M., and Stephens, J.C., 1967, Geology and hydrology of Clay County, South Dakota: South Dakota Geological Survey Bulletin 19, pt. 2, 62 p., scale 1:210,000.
*Duchossois, G.E., 1985, Bedrock topography in north central South Dakota: Vermillion, S.D., South Dakota Geological Survey, unpublished map, scale 1:250,000.
*Gilbertson, J.P., 1985, Thickness of Quaternary deposits, northeastern South Dakota: Vermillion, S.D., South Dakota Geological Survey, unpublished map, scale 1:250,000.
*Hedges, L.S., Burch, S.L., Iles, D.L., Barari, R.A., and Schoon, R.A., 1982, Evaluation of ground-water resources, eastern South Dakota and upper Big Sioux River, South Dakota and Iowa, tasks 1, 2, 3, and 4: South Dakota Geological Survey U.S. Army Corps of Engineers Contract DACW45–80–C–0185, scale 1:500,000.
Howells, L.W., and Stephens, J.C., 1968, Geology and water resources of Beadle County, South Dakota: South Dakota Geological Survey Bulletin 18, pt. 2, 63 p., scale 1:350,000.
Koch, N.C., 1969, Effects of reservoir filling on a buried aquifer of glacial origin in Campbell County, South Dakota: U.S. Geological Survey Professional Paper 650–B, p. B169–B173.
Kume, Jack, 1977, Geology and water resources of Charles Mix and Douglas Counties, South Dakota: South Dakota Geological Survey Bulletin 22, pt. 2, 31 p., scale 1:300,000.
Tomhave, D.W., 1985, Drift thickness data in Minnehaha County, South Dakota: Vermillion, S.D., South Dakota Geological Survey, unpublished data.
U.S. Army Corps of Engineers, 1948, Geologic sections of the Oahe dam site: Vermillion, S.D., South Dakota Geological Survey.

VERMONT

Overview of Quaternary deposits.—Surface sediments in Vermont are dominantly sandy till. Large areas of stratified deposits are confined to lowlands; these deposits are dominantly fine grained in the Champlain and Connecticut River valleys and coarse grained in other river valleys and in deltaic deposits bordering the Champlain lowlands. Sediment thickness in Vermont is generally less than 50 ft; in mountainous areas, the till cover is patchy and bedrock is exposed in many places. Thicker sediment is confined to valleys, where as much as 100 ft of stratified sediment is preserved.

Surficial information.—A statewide surficial map (Stewart and MacClintock, 1970), scale 1:250,000, was used to compile the Quaternary sediments map. A reconnaissance soil map was used to map areas of patchy till. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from hundreds of data points obtained from State well-log files and from well data and cross sections in 12 publications. The reliability of the map data is considered to be low.

Subsurface information.—Although the character and geometry of subsurface glacial deposits are not well known, the general nature of the subsurface deposits in the Connecticut River valley and beneath glacial deltas in the Lake Champlain valley is shown.

Surficial and Stack-Unit Information

Latimer, W.J., Perkins, S.O., Lesh, F.R., Smith, L.R., and Goodman, K.V., 1930, Soil survey (reconnaissance) of Vermont: Washington, D.C., U.S. Soil Conservation Service, 80 p.

*Stewart, D.P., and MacClintock, P., 1970, Surficial geologic map of Vermont: Waterbury, Vt., Vermont Geological Survey, scale 1:250,000.

Thickness Information

Hodges, A.L., Jr., and Butterfield, D., 1966–68, Ground water favorability maps of the Missisquoi, Lake Memphremagog, Nulhegan-Passumpsic, Lamoille, Winooski, Otter Creek, White, Wells-Ompompanoosuc, Ottauquechee-Saxtons, Batten, Walloomsac, Hoosic, and West-Deerfield river basins, Vermont: Montpelier, Vt., Vermont Department of Water Resources, scale approx. 1:125,000.

Hodges, A.L., Jr., Butterfield, D., and Ashley, J.W., 1976, Ground-water resources of the Barre-Montpelier area, Vermont: Montpelier, Vt., Vermont Department of Water Resources, scale 1:48,000.

———1976, Ground-water resources of the White River Junction area, Vermont: Montpelier, Vt., Vermont Department of Water Resources, scale 1:48,000.

Hodges, A.L., Jr., Willey, R.E., Ashley, J.W., and Butterfield, D., 1977, Ground-water resources of the Upper Winooski river basin, Vermont: U.S. Geological Survey Water-Resources Investigations Report 77–120, 27 p., scale 1:48,000.

Stedman, G.D., Thiel, S.A., and Butterfield, D., 1980, Vermont ground water pollution source inventory, December, 1980: Montpelier, Vt., Vermont Department of Water Resources and Environmental Engineering, 138 p.

Stewart, D.P., 1971, Geology for environmental planning in the Barre-Montpelier region, Vermont: Vermont Geological Survey Environmental Geology no. 1, 32 p.

———1972, Geology for environmental planning in the Rutland-Brandon region, Vermont: Vermont Geological Survey Environmental Geology no. 2, 40 p.

———1973, Geology for environmental planning in the Burlington-Middlebury region, Vermont: Vermont Geological Survey Environmental Geology no. 3, 44 p.

———1974, Geology for environmental planning in the Milton-St. Albans region, Vermont: Vermont Geological Survey Environmental Geology no. 5, 48 p.

———1975, Geology for environmental planning in the Brattleboro-Windsor region, Vermont: Vermont Geological Survey Environmental Geology no. 7, 46 p.

*Vermont Department of Water Resources, Montpelier, Vt., unpublished file of well logs.

Willey, R.E., and Butterfield, D., 1983, Ground-water resources of the Rutland area, Vermont: U.S. Geological Survey Water-Resources Investigations Report 82–4057, scale 1:48,000.

Wright, F.M., 1974, Geology for environmental planning in the Johnson-Hardwick region, Vermont: Vermont Geological Survey Environmental Geology no. 4, 59 p.

Additional References

Chapman, D.H., 1937, Late-glacial and postglacial history of the Champlain valley: American Journal of Science, 5th ser., v. 34, no. 200, p. 89–124. (Limit of late Wisconsinan marine invasion)

Doll, C.G., Cady, W.M., Thompson, J.B., and Billings, M.P., 1961, Geologic map of Vermont: Waterbury, Vt., Vermont Geological Survey, scale 1:250,000. (Till texture)

WISCONSIN

Overview of Quaternary deposits.—Surface sediments in Wisconsin are dominantly sandy till, except near Lake Michigan, where tills are silty and clayey. Coarse-grained stratified deposits cover large areas of the uplands in northern and central Wisconsin, especially where glacial interlobate areas existed. Near the Great Lakes and near the nonglaciated area of southwestern Wisconsin, sediment thickness generally is less than 50 ft; in places, the till cover is patchy and bedrock exposures are numerous. In southeastern Wisconsin and on the uplands of northern and central Wisconsin, sediment thicknesses are greater, exceeding 100 ft in many places.

Surficial information.—The distribution of surface sediments was compiled from 35 sources, whose scales ranged from 1:15,840 to 1:1,000,000; mapping emphasis ranged from statewide soil surveys to detailed surficial geologic maps. The reliability of the map data is considered to be moderately low.

Thickness information.—The thickness information for the Quaternary sediments map was compiled mostly from a generalized statewide map by Trotta and Cotter (1973), scale 1:1,000,000. The reliability of the map data is considered to be moderately low.

Subsurface information.—Although the character and geometry of subsurface glacial deposits are not well known, the character of buried sediments in the area inundated by glacial lakes near Green Bay and Lake Winnebago was shown, albeit diagrammatically, because these glacial lake sediments are thin and discontinuous.

Surficial and Stack-Unit Information

Alden, W.C., 1918, The Quaternary geology of southeastern Wisconsin: U.S. Geological Survey Professional Paper 106, 356 p., scale 1:250,000.
Attig, J.W., 1985, Pleistocene geology of Vilas County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 50, 32 p., scale 1:100,000.
Barndt, W.D., Lorenz, H.E., Frings, S.W., Link, E.G., and others, 1978, Soil survey of Outagamie County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 129 p., scale 1:190,080 and 1:15,840.
Bell, E.A., and Sherrill, M.G., 1974, Water availability in central Wisconsin—An area of near-surface crystalline rock: U.S. Geological Survey Water-Supply Paper 2022, 32 p., scale 1:125,000.
Clayton, Lee, 1984, Pleistocene geology of the Superior region, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 46, 40 p., scale 1:250,000.
———1986, Pleistocene geology of Florence County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 51, 13 p., scale 1:100,000.
———1986, Pleistocene geology of Portage County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 56, 19 p., scale 1:100,000.
———1987, Pleistocene geology of Adams County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 59, 14 p., scale 1:100,000.
Engel, R.J., Gundlach, H.F., Schmude, K.O., Glocker, C.L., Weber, E.L., and Anderson, F.L., 1974, Soil survey of Rock County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 160 p., scale 1:190,080 and 1:20,000.
Engel, R.J., Roberts, B.A., Steingraeber, J.A., Barndt, W.D., and Moeller, H.T., 1978, Soil survey of Sheboygan County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 116

p., scale 1:190,080 and 1:15,840.
Farrand, W.R., Mickelson, D.M., Cowan, W.R., and Goebel, J.E., 1984, Quaternary geologic map of the Lake Superior 4°x6° quadrangle, United States and Canada, in Richmond, G.M., and Fullerton, D.S., eds., Quaternary geologic atlas of the United States: U.S. Geological Survey Miscellaneous Investigations Series Map I–1420 (NL–16), scale 1:1,000,000.
Geib, W.J., Taylor, A.E., and Conrey, Guy, 1913, Soil survey of Columbia County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 61 p., scale 1:62,500.
Glocker, C.L., Ayen, J.E., Omernik, D.L., Steingraeber, J.A., Suhs, S.C., and Watson, B.G., 1979, Soil survey of Jefferson County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 169 p., scale 1:190,080 and 1:15,840.
Goebel, J.E., Mickelson, D.M., Farrand, W.R., Clayton, Lee, and others, 1983, Quaternary geologic map of the Minneapolis 4_x6_ quadrangle, United States, in Richmond, G.M., and Fullerton, D.S., eds., Quaternary geologic atlas of the United States: U.S. Geological Survey Miscellaneous Investigations Series Map I–1420 (NL–15), scale 1:1,000,000.
Gundlach, H.F., Roberts, D.C., Slota, R.W., and Widdel, K.H., 1980, Soil survey of Sauk County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 248 p., scale 1:253,440 and 1:15,840.
Hadley, D.W., 1976, Glacial deposits of Wisconsin: sand and gravel resource potential: Madison, Wis., Wisconsin Geological and Natural History Survey, 19 p., scale 1:500,000.
Hole, F.D., and others, 1968, Soils of Wisconsin: Madison, Wis., Wisconsin Geological and Natural History Survey, scale 1:710,000.
Hutchinson, R.D., 1970, Water resources of Racine and Kenosha Counties, southeastern Wisconsin: U.S. Geological Survey Water-Supply Paper 1878, 63 p., scale 1:125,000.
Knox, J.C., Attig, J.W., and Johnson, M.D., 1982, Pre-Wisconsinan deposits in the Bridgeport terrace of the lower Wisconsin River valley, in Quaternary history of the driftless area, 29th annual meeting, Midwest Friends of the Pleistocene: Wisconsin Geological and Natural History Survey Field Trip Guidebook 5, p. 103–118.
Lineback, J.A., Bleuer, N.K., Mickelson, D.M., Farrand, W.R., and Goldthwait, R.P., 1983, Quaternary geologic map of the Chicago 4°x6° quadrangle, United States, in Richmond, G.M., and Fullerton, D.S., eds., Quaternary geologic atlas of the United States: U.S. Geological Survey Miscellaneous Investigations Series Map I–1420 (NK–16), scale 1:1,000,000.
Link, E.G., Elmer, S.L., Vanderveen, S.A., Barndt, W.D., and others, 1978, Soil survey of Door County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 132 p., scale 1:316,800 and 1:15,840.
Link, E.G., Frings, S.W., Campbell, J.E., Kidney, K.A., Otter, A.J., and Suhr, M.C., 1980, Soil survey of Kewaunee County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 187 p., scale 1:190,080 and 1:15,840.
Link, E.G., Higgins, Richard, Korth, I.L., and Patzer, R.A., 1973, Soil survey of Fond Du Lac County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 115 p., scale 1:190,080 and 1:15,840.
Link, E.G., Leonard, C.F., Lorenz, H.E., Barndt, W.D., and others, 1974, Soil survey of Brown County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 119 p., scales 1:190,080 and 1:20,000.
Mickelson, D.M., 1983, A guide to the glacial landscapes of Dane County, Wisconsin: Wisconsin Geological and Natural History Survey Field Trip Guidebook 6, 53 p., scale 1:100,000.
———1985, unpublished data for southwestern Wisconsin, prepared for U.S. Geological Survey Miscellaneous Investigations Series Map I–1420 (Quaternary geologic atlas of the United

States, Des Moines 1:1,000,000 quadrangle), 1 sheet.
Mitchell, M.J., Babik, N.R., Denow, K.A., Nazke, L.L., and Roberts, B.A., 1980, Soil survey of Winnebago County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 182 p., scale 1:190,080 and 1:20,000.
Need, E.A., 1985, Pleistocene geology of Brown County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 48, 19 p., scale 1:200,000.
Otter, A.J., Butman, B.S., Campbell, J.E., Kidney, K.A., and others, 1980, Soil survey of Calumet and Manitowoc Counties, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 176 p., scale 1:253,440 and 1:15,840.
Otter, A.J., Campbell, J.E., Frings, S.W., Simeth, F.J., Simonson, D.T., and Suhs, S.C., 1984, Soil survey of Waupaca County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 167 p., scale 1:253,440 and 1:15,840.
Roberts, D.C., Campbell, J.E., and Kroll, T.L., 1988, Soil survey of Oconto County, Wisconsin: Marinette, Wis., U.S. Soil Conservation Service. Pre-publication map obtained for this compilation, at scale 1:316,800.
Schmude, K.O., Demo, O.E., Fanning, D.S., Langton, J.E., Peck, T.R., and Lee, G.B., 1975, Soil survey of Marquette County, Wisconsin: Washington, D.C., U.S. Soil Conservation Service, 91 p., scale 1:190,080 and 1:20,000.
Summers, W.K., 1965, Geology and ground-water resources of Waushara County, Wisconsin: U.S. Geological Survey Water-Supply Paper 1809–B, 32 p., scale 1:62,500.
Thwaites, F.T., 1943, Pleistocene of part of northeastern Wisconsin: Geological Society of America Bulletin, v. 54, p. 87–144, scale 1:250,000.
Thwaites, F.T., and Bertrand, Kenneth, 1957, Pleistocene geology of the Door Peninsula, Wisconsin: Geological Society of America Bulletin, v. 68, p. 831–880, scale 1:250,000.

Thickness Information

Clayton, Lee, 1984, Pleistocene geology of the Superior region, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 46, 40 p., scale 1:1,000,000.
*Trotta, L.C., and Cotter, R.D., 1973, Depth to bedrock in Wisconsin: Madison, Wis., Wisconsin Geological and Natural History Survey, scale 1:1,000,000.

GREAT LAKES

Overview of Quaternary deposits.—Surficial bottom sediments in the Great Lakes are dominantly fine-grained stratified glacial lake sediments and Holocene muds. In places, till or rock underlie the lake bottom, particularly in coastal areas. Sediment thicknesses vary greatly for the different lakes. In eastern Lake Superior, sediment thicknesses are generally less than 100 ft except over buried valleys or grooves gouged out by the ice. In the western part of the lake, sediments commonly exceed 200 ft in thickness, and, in the deepest parts of the basin, they exceed 800 ft. In Lake Michigan, sediment thickness in the southern basin is generally less than 100 ft, whereas, in the central basin, thicknesses exceed 400 ft in places. No data are available for northern Lake Michigan. In Lake Huron, sediment thicknesses in the axis of the basin are commonly more than 100 ft and in places exceed 200 ft, whereas, elsewhere in the lake, the sediment is much thinner, generally less than 50 ft. In the westernmost part of Lake Erie, sediments are mostly less than 50 ft thick. To the east, sediments thicken, and in the east-central part of the lake, sediments exceed 200 ft in thickness. Along the lake margins, however, sediments thin to less than 50 ft. Unlike Lake Erie, Lake Ontario is only partly filled with sediment. Even along the axis of the basin, less than 100 ft of sediment is present. In Lake Champlain, sediments are generally thin except in a series of narrow ice-gouged channels in the central part of the lake.

Surficial information.—The Quaternary sediments map was compiled from five publications, which show the bottom sediment distribution in a highly generalized fashion. The reliability of the map data is considered to be moderately low.

Thickness information.—Sediment thickness was determined from several published and unpublished sources, containing data as varied as sediment thickness, bedrock-surface topography, and cross sections. The reliability of the map data is considered to be moderately low.

Subsurface information.—No attempt was made to characterize buried units beneath the Great Lakes.

Character of Lake-Bottom Sediments

Dell, C.I., 1976, Sediment distribution and bottom topography of southeastern Lake Superior: Journal of Great Lakes Research, v. 2, no. 1, p. 164–176.

Lineback, J.A., Gross, D.L., and Meyer, R.P., 1974, Glacial tills under Lake Michigan: Illinois State Geological Survey Environmental Geology Notes no. 69, 48 p., scale 1:1,750,000.

*Thomas, R.L., 1981, Sediments of the North American Great Lakes: Internationale Vereinigung f_r Theoretische und Angewandte Limnologie Verhandlungen [International Association of Theoretical and Applied Limnology Proceedings], v. 21, pt. 3, p. 1666–1680.

Thomas, R.L., Kemp, A.L., and Lewis, C.F.M., 1972, Distribution, composition and characteristics of the surficial sediments of Lake Ontario: Journal of Sedimentary Petrology, v. 42, p. 66–84.

———1973, The surficial sediments of Lake Huron: Canadian Journal of Earth Sciences, v. 10, p. 226–271.

Thickness of Quaternary Sediment Beneath the Great Lakes

Carter, C.H., Williams, S.J., Fuller, J.A., and Meisburger, E.P., 1982, Regional geology of the southern Lake Erie (Ohio) bottom: A seismic reflection and vibracore study: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Miscellaneous Report 82–15, 109 p.

Dames and Moore, 1974, Airport feasibility study for the Lake Erie Regional Transportation Authority, and preliminary study, 1970: Sandusky, Ohio, Ohio Geological Survey.

Hobson, G.D., Herdendorf, C.E., and Lewis, C.F.M., 1969, High resolution reflection seismic survey in western Lake Erie, in Proceedings of the 12th Conference on Great Lakes Research: Ann Arbor, Mich., International Association for Great Lakes Research, p. 210–224.

Hunt, A.S., 1977, Sediment thicknesses, eastern Lake Champlain: Burlington, Vt., A completion report submitted to the Vermont Water Resources Research Center and the U.S. Department of the Interior, Office of Research and Technology, 31 p., scale 1:175,000.

Lewis, C.F.M., 1986, Unpublished maps of Lake Huron bedrock topography [scale 1:400,000]; Bedrock contours and drift thickness contours, eastern Lake Erie [scale 1:400,000]; Total thickness of sediments, eastern Lake Erie (one-way travel time) [scale 1:200,000]; Thickness of sediments in Lake Ontario (one-way travel time) [scale 1:200,000]; Thickness of sediments in western Lake Ontario (one-way travel time) [scale approx. 1:72,000]: Dartmouth, Nova Scotia, Canada, Atlantic Geoscience Centre, Bedford Institute of Oceanography.

Lineback, J.A., Gross, D.L., and Meyer, R.P., 1972, Geologic cross sections derived from seismic profiles and sediment cores from southern Lake Michigan: Illinois State Geological Survey

Environmental Geology Notes no. 54, 43 p.
Wall, R.E., 1968, A sub-bottom reflection survey in the central basin of Lake Erie: Geological Society of America Bulletin, v. 79, p. 91–106.
Wickham, J.T., Gross, D.L., Lineback, J.A., and Thomas, R.L., 1978, Late Quaternary sediments of Lake Michigan: Illinois State Geological Survey Environmental Geology Notes no. 84, 26 p.
Williams, S.J., and Meisburger, E.P., 1982, Geological character and mineral resources of south central Lake Erie: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Miscellaneous Report 82–9, 62 p.
Wold, R.J., 1979, Maps showing bedrock topography of Lake Superior: U.S. Geological Survey Miscellaneous Field Studies Map MF–1174, scale 1:600,000.
Wold, R.J., Paull, R.A., Wolosin, C.A., and Friedel, R.J., 1981, Geology of central Lake Michigan: American Association of Petroleum Geologists Bulletin, v. 65, no. 9, p. 1621–1632, scale approx. 1:1,000,000.

ATLANTIC OFFSHORE

Overview of Quaternary deposits.—In general, surficial bottom sediments are dominantly fine grained and stratified in Long Island Sound and eastward to roughly the Rhode Island-Massachusetts line. To the east, around Cape Cod, and northward to offshore New Hampshire, coarser grained stratified sediments dominate. Along the Maine coast, till and fine-grained stratified bottom deposits are common. From Long Island Sound eastward to the limit of data at Nantucket Island, sediment thickness exceeds 400 ft over buried valleys; on the submarine uplands, less than 100 ft of sediment is common. North of Cape Cod, sediment thickness is variable but generally thins northward. In offshore areas of Maine, sediment is less than 50 ft thick in most places, exceeding 100 ft only in large buried valleys.

Surficial information.—Fifteen sources were used in the Quaternary sediments map compilation. Bottom grab samples, which sample only the upper few inches of the sea floor, were the most common data available. On some source maps, lithology was estimated by seismic characteristics. Overall, the reliability of the map data is considered to be moderately low.

Thickness information.—In many areas, the thickness of Holocene sediments and thickness of glacial sediments were computed at points along seismic tracklines and were used to calculate total Quaternary sediment thickness. In other areas, bedrock-surface contour maps and bathymetric maps were available, and sediment thickness was computed from those. The reliability of the map data is considered to be moderately high.

Subsurface information.—No attempt was made to characterize buried units offshore.

Character of Bottom Sediments

Birch, F.S., 1984, A geophysical study of sedimentary deposits on the inner continental shelf of New Hampshire: Northeastern Geology, v. 6, no. 4, p. 207–221.
Folger, D.W., O'Hara, C.J., and Robb, J.M., 1975, Maps showing bottom sediments on the continental shelf of the northeastern United States—Cape Ann, Massachusetts to Casco Bay, Maine: U.S. Geological Survey Miscellaneous Investigations Series Map I–839, scale 1:125,000.
Kelley, J.T., 1986, written communication of data later released as:
Kelley, J.T., and Belknap, D.F., 1988, Geomorphology and sedimentary framework of the inner continental shelf of central Maine: Maine Geological Survey Open-File Report 88–6, 51 p.

Kelley, J.T., Belknap, D.F., and Shipp, R.C., 1987, Geomorphology and sedimentary framework of the inner continental shelf of south-central Maine: Maine Geological Survey Open-File Report 87–19, 76 p.

———1987, Geomorphology and sedimentary framework of the inner continental shelf of southwestern Maine: Maine Geological Survey Open-File Report 87–5, 85 p.

Knebel, H.J., and Scanlon, K.M., 1985, Maps showing sea-floor topography, depth to bedrock, and sediment thickness, Penobscot Bay, Maine: U.S. Geological Survey Miscellaneous Field Studies Map MF–1751, scale 1:100,000.

Needell, S.W., and Lewis, R.S., 1984, Geology and structure of Block Island Sound, Rhode Island and New York: U.S. Geological Survey Miscellaneous Field Studies Map MF–1621, scale 1:125,000.

Needell, S.W., O'Hara, C.J., and Knebel, H.J., 1983, Quaternary geology of the Rhode Island inner shelf: Marine Geology, v. 53, p. 41–53, scale approx. 1:360,000.

O'Hara, C.J., and Oldale, R.N., 1980, Maps showing geology and shallow structure of eastern Rhode Island Sound and Vineyard Sound, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–1186, scale 1:125,000.

———1987, Maps showing geology, shallow structure, and bedform morphology of Nantucket Sound, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–1911, scale 1:125,000.

Robb, J.M., and Oldale, R.N., 1977, Preliminary geologic maps, Buzzards Bay, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–889, scale approx. 1:100,000 and 1:160,000.

Schlee, John, Folger, D.W., and O'Hara, C.J., 1973, Bottom sediments on the continental shelf off the northeastern United States—Cape Cod to Cape Ann, Massachusetts: U.S. Geological Survey Miscellaneous Investigations Series Map I–746, scale 1:125,000.

Stone, J.R., Stone, B.D., and Lewis, R.S., 1986, Late Quaternary deposits of the southern Quinnipiac-Farmington lowland and Long Island Sound basin: their place in a regional stratigraphic framework: Connecticut Geological and Natural History Survey Guidebook 6, p. 535–575.

Williams, S.J., 1976, Geomorphology, shallow subbottom structure, and sediments of the Atlantic inner continental shelf off Long Island, New York: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Technical Paper no. 76–2, 123 p.

———1981, Sand resources and geological character of Long Island Sound: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Technical Paper no. 81–3, 65 p., scale 1:750,000.

Thickness of Quaternary Sediment

Birch, F.S., 1984, A geophysical study of sedimentary deposits on the inner continental shelf of New Hampshire: Northeastern Geology, v. 6, no. 4, p. 207–221.

Grim, M.S., Drake, C.L., and Heirtzler, J.R., 1970, Sub-bottom study of Long Island Sound: Geological Society of America Bulletin, v. 81, p. 649–666, scale approx. 1:700,000.

Haeni, F.P., and Sanders, J.E., 1974, Contour map of the bedrock surface, New Haven-Woodmont quadrangles, Connecticut: U.S. Geological Survey Miscellaneous Field Studies Map MF–557–A, scale 1:24,000.

Kelley, J.T., 1986, written communication of data later released as:

Kelley, J.T., and Belknap, D.F., 1988,

Geomorphology and sedimentary framework of the inner continental shelf of central Maine: Maine Geological Survey Open-File Report 88–6, 51 p.
Kelley, J.T., Belknap, D.F., and Shipp, R.C., 1987, Geomorphology and sedimentary framework of the inner continental shelf of south-central Maine: Maine Geological Survey Open-File Report 87–19, 76 p.
———1987, Geomorphology and sedimentary framework of the inner continental shelf of southwestern Maine: Maine Geological Survey Open-File Report 87–5, 85 p.
Knebel, H.J., and Scanlon, K.M., 1985, Maps showing sea-floor topography, depth to bedrock, and sediment thickness, Penobscot Bay, Maine: U.S. Geological Survey Miscellaneous Field Studies Map MF–1751, scale 1:100,000.
Lewis, R.S., and Needell, S.W., 1987, Maps showing the stratigraphic framework and Quaternary geologic history of eastern Long Island Sound: U.S. Geological Survey Miscellaneous Field Studies Map MF–1939–A, 7 p., 3 sheets, scale 1:125,000.
McMaster, R.L., and Ashraf, Asaf, 1973, Extent and formation of deeply buried channels on the continental shelf off southern New England: Journal of Geology, v. 81, p. 374–379.
O'Hara, C.J., and Oldale, R.N., 1980, Maps showing geology and shallow structure of eastern Rhode Island Sound and Vineyard Sound, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–1186, scale 1:125,000.
Oldale, R.N., 1985, U.S. Geological Survey, written communication. For parts of the offshore area of this map (central and eastern Long Island Sound, Block Island Sound, Cape Cod Bay, Nantucket Sound, Massachusetts Bay, and offshore from Cape Ann to New Hampshire line), seismic data supplied by Oldale were used to compile the combined thickness of glacial and Holocene sediments.
Robb, J.M., and Oldale, R.N., 1977, Preliminary geologic maps, Buzzards Bay, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–889, scale 1:160,000.
Smolensky, D.A., Buxton, H.T., and Shernoff, P.K., in press, Hydrogeologic framework of Long Island, New York: U.S. Geological Survey Hydrologic Investigations Atlas HA–709, scale 1:125,000.
Tuttle, C.R., Allen, W.B., and Hahn, G.W., 1961, A seismic record of Mesozoic rocks on Block Island, Rhode Island: U.S. Geological Survey Professional Paper 424–C, p. C254–C256.
Williams, S.J., 1976, Geomorphology, shallow subbottom structure, and sediments of the Atlantic inner continental shelf off Long Island, New York: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Technical Paper no. 76–2, 123 p.

ONTARIO, CANADA

Overview of Quaternary deposits.—In southern Ontario, surface sediments are dominantly silty till, except in the Great Lakes lowlands where the till is clayey. Large areas of stratified deposits, generally coarse grained, are present throughout southern Ontario and are especially common near Lake Erie. Sediment thickness is mostly between 50 and 200 ft; near the northern coast of Lake Erie and north of Lake Ontario, thicknesses exceed 200 ft.

Surficial information.—A surficial map of southern Ontario (Chapman and Putnam, 1984), scale 1:600,000, was used to compile the Quaternary sediments map. Minor reinterpretation was required to adapt map units to the classification scheme of the Quaternary sediments map. The reliability of the map data is considered to be moderately high.

Thickness information.—A sediment-thickness map prepared by the Ontario Geological

Survey (Sado and Easton, 1985), scale 1:125,000, was used to compile the Quaternary sediments map. The reliability of the map data is considered to be moderate.

Subsurface information.—No attempt was made to characterize the subsurface deposits of southern Ontario.

Surficial Information

*Chapman, L.J., and Putnam, D.F., 1984, The physiography of southern Ontario (3d ed.): Ontario Geological Survey Special Volume 2, 270 p., scale 1:600,000.

Zoltai, S.C., 1965, Kenora-Rainy River, surficial geology: Ontario Department of Lands and Forests, Map S165, scale 1:506,880.

Thickness Information

Sado, E.V., and Easton, J., 1985, Compilation of drift thickness data for Toronto-Windsor-Bruce Peninsula area: Toronto, Ont., Ontario Geological Survey, unpublished maps, scale 1:125,000.

Figure Captions

Figure 1. Index map showing outline of the four maps in this series (Soller, in press a,b,c,d). The mapped area is shaded.

Figure 2. Relative reliability of the surficial geologic data, by State, and the degree to which existing State surficial maps were revised for this study. The degree of revision largely reflects differences in the emphasis of available surficial mapping (for example, stratigraphy, geomorphology, or sediment type). The status and detail of surficial mapping vary greatly from State to State. For example, for Massachusetts and Connecticut, maps of surficial materials have been compiled at 1:125,000 scale from 1:24,000-scale maps, and these data could be used in this map with no revision. For New York and New Hampshire, detailed surficial geologic mapping is sparse, and the data for this map had to be compiled from a combination of geologic reconnaissance, soil, and topographic maps.

Figure 3. Range of particle sizes in the mapped surficial units (adapted from Stone and others, 1979, figs. 2, 3).

Figure 4. Relative reliability of Quaternary sediment-thickness data, by State, and the degree to which existing State maps were revised for this study. The degree of revision reflects differences in the type of thickness data available and addition of new data by the author. The status and detail of thickness mapping vary greatly from State to State. For example, for Massachusetts and Connecticut, thickness mapping has been compiled at 1:125,000 scale from detailed data, and the compilation could be used in this map with no revision. For New York and New Hampshire, information is sparse, and the thickness data for this map had to be gathered from widely scattered well-log data and a few geologic reports.

Figure 5. Texture of surficial till, based on U.S. Department of Agriculture textural classification. Textural descriptions from field mappers and some textural analyses were used to compile most of this map. For some places, notably Montana, data were quite sparse, and the lithology of the bedrock was used as the main guide to texture. In general, however, the map was compiled without reference to the bedrock lithology. See text for a discussion of till texture.

Figure 6. General lithology of bedrock directly beneath the Quaternary sediments. Lithologies are grouped according to dominant grain size and rock origin. The outlines of major glacial lakes are also shown because ice flowing in glacial lake basins commonly incorporated preexisting lake sediments into the till. Till texture (fig. 5) was greatly influenced by bedrock lithology and major glacial lake basins.

Figure 7. Simplified thickness map of Quaternary sediments within the mapped area and late Wisconsinan glacial lobe positions (from Mickelson and others, 1983) as shown by medium-weight solid lines. Some lobe positions, especially in the Eastern United States, have been omitted here for clarity. Only the 200- and 400-ft thickness contours are shown. Dashed line, labeled "limit of map area," shows the maximum extent of glacial ice. Dotted line shows location of Appalachian Escarpment (AE) in Ohio only. LE, Lake Erie lobe; LH, Lake Huron lobe; S, Saginaw lobe; LM, Lake Michigan lobe; LS, Lake Superior lobe; RR, Red River lobe; DM, Des Moines lobe; J, James lobe. Cross sections along lines A–A’, B–B’, and C–C’ are shown in figure 8.

Figure 8. Cross sections showing the relations among bedrock topography, Quaternary sediment thickness, and ice lobation. Stippled areas represent Quaternary sediment. Locations of sections shown in figure 7. Cross section C–C' shows the thick sediment over the bedrock high, which was deposited between two sublobes of the Lake Superior lobe.